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MECHANICAL DRAFTING

CHARLES B. HOWE

WILEY TECHNICAL SERIES

MECHANICAL DRAFTING

BY

CHARLES B. HOWE, M.E.

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FIRST THOUSAND

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PREFACE

THIS book is written for the purpose of assisting the student to a knowledge of the principles of mechanical drawing and their practical applications. It is not intended to be a manual of self-instruction, but rather an assistant to the teacher in reinforcing his presentation of the subject matter and in supplying him with convention, data, and problem sheets, the preparation of which ordinarily consumes much of his time and energy.

It is believed that the treatment of the subject, as presented here, will be found to stimulate the interest of the student and to serve a much more useful purpose than does the formal drawing usually taught.

A course of study will not be found in this book. A definite course planned to cover all schools would be adapted to none, because conditions vary locally and are changing from year to year; but any teacher may select and arrange a course, closely adapted to his needs, from the supplementary loose-leaf sheets which are published with the Drafting Series. These sheets contain informational instruction, such as conventions and data, and also problems. A list of these sheets may be procured from the publishers of this book. Additions to the list will be made from time to time, and teachers are requested to correspond with the author and to express their views and wishes.

The plan of supplying a text, the principles of which do not change greatly from year to year, in combination with loose-leaf sheets, which can be selected and arranged to suit individual requirements, will enable a large number of teachers to formulate a course of study adapted to the needs of their classes.

Drawing instruments and materials generally are furnished by the schools and therefore all information relating to their selection is omitted.

The author believes that the chief value of a knowledge of mechanical drawing is its utility as a medium of expression, and this text has been prepared from this point of view. There can be no question, also, as to its helpfulness in the study of applied geometry, but the amount of time that

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may usually be devoted to mechanical drawing is so limited the author feels that it should be spent entirely in acquiring a knowledge of and skill in drafting rather than in the solution of numerous geometrical problems, which are seldom used in practice, and most of which can be solved by the use of T square and triangle instead of by geometrical methods.

On the other hand, the study of orthographic projection is essential to a thorough course in mechanical drawing. Projection should be presented through the *solid*, avoiding as much as possible the difficult terms and methods of descriptive geometry. The *third angle*, only, should be studied for the following reasons: First, it is used almost exclusively in drafting offices; second, the principles of projection are the same for all angles; third, a better understanding of the subject will be secured by concentrated drill upon the principles as applied to one angle only.

The sequence of the subject as here presented is more a matter of convenience than an arrangement for a course of study. The author has made it a practice to begin with very simple working drawings and to introduce isometric drawing, after a few lessons, translating freely from one form of expression to the other. This method will greatly assist the pupil in learning to read drawings, i. e., *to visualize the object*. In this stage, the *actual object* should be employed as the basis of the freehand sketch, which may be rendered either in views or isometric. Considerable emphasis should be placed upon this phase of the instruction and several lessons should be given in the above manner, preceding the use of instruments.

Following this there should be considerable practice in the application of principles in the making of isometric and working drawings with instruments, both in detail and assembly. Simple projections, without dimensions and omitting all reference to the theory, may be presented next.

Simple problems in machine and plan drawing, working from sketches, models and blue-prints are next in order. Isometric and perspective sketches should be used freely in presenting the material for working drawings. Mere copying from blue-prints should be avoided except for purposes of conventional rendering. In drawing plans the pupil should begin with the representation of a very simple floor plan and elevation drawn to a scale of $\frac{1}{4}$ in. = 1 ft. The representation of doors and windows in elevation should then be studied and applied to a simple problem. This should be followed by studies of structural details in section and isometric drawing. Next, he should copy the plans and elevations from a good design of a small house, making only slight modifications as directed by the instructor. After obtaining some proficiency in problems of this character he may essay to work a problem from his own sketches.

After the pupil has studied geometry as a mathematical subject, the principles of orthographic projection should

be taught, followed by intersections and developments. He will then be ready to undertake advanced drafting courses along some special line leading eventually to skill and thoroughness in that branch.

The teacher should always insist that drawings be "blocked in" by fine, light, solid lines which are to be left on the finished drawing but not inked. This will facilitate the checking of drawings and will also serve as an indication that the pupil is following practical methods in drafting.

In conclusion, the author acknowledges the courtesy of those who have loaned drawings, photographs, and cuts for reproduction, and desires to mention in particular the following: The National Fireproofing Co., Eugene Dietzgen Co., F. E. Brandis Sons & Co., The Revolute Machine Co., The C. F. Pease Co., The Pratt & Whitney Co.

CHARLES B. HOWE.

NEW YORK,
May, 1915.

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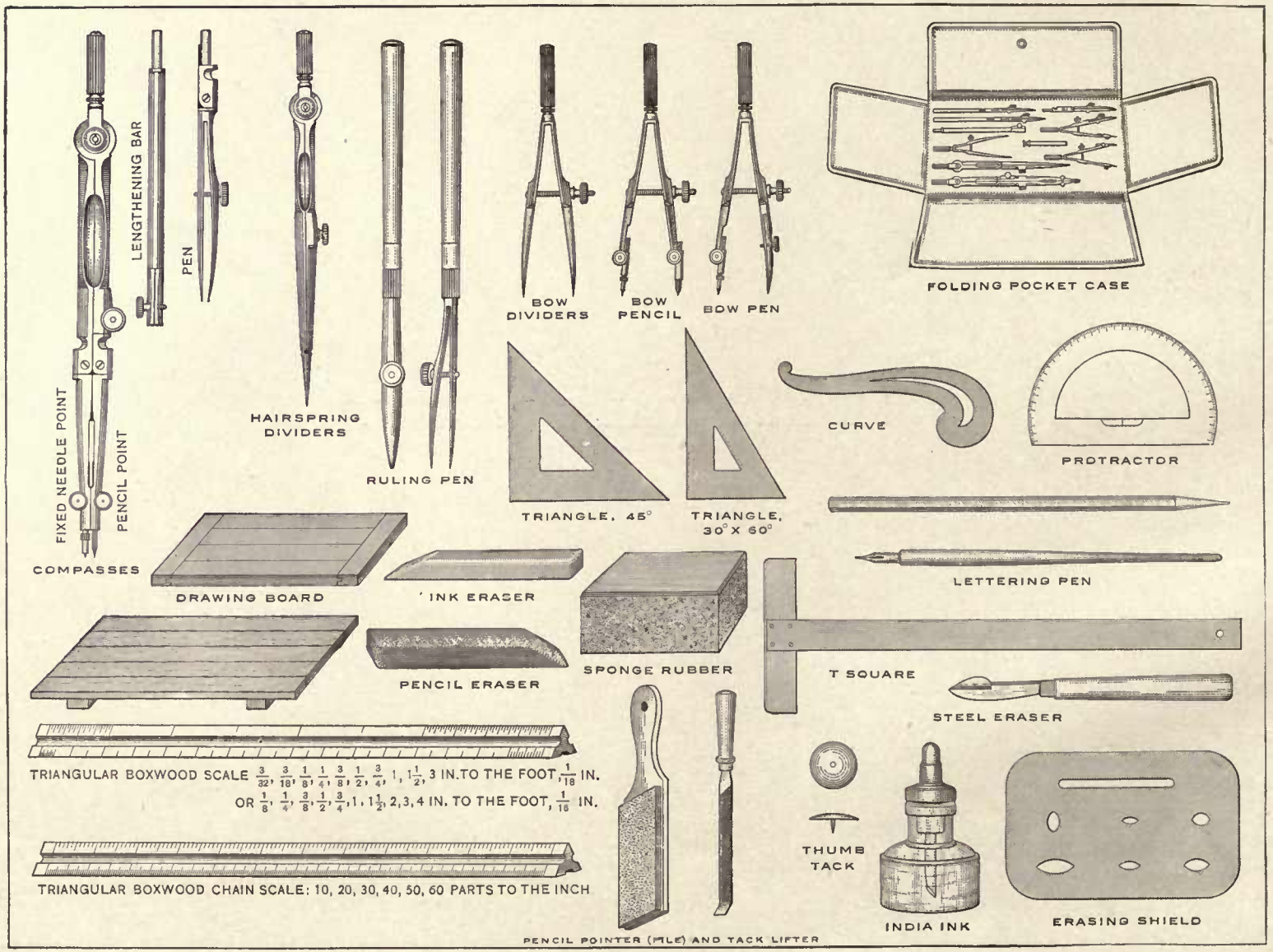
MECHANICAL DRAFTING


LENGTHENING BAR
PEN
FIXED NEEDLE POINT
PENCIL POINT
COMPASSES
HAIRSPRING DIVIDERS
RULING PEN
BOW DIVIDERS
BOW PENCIL
BOW PEN
FOLDING POCKET CASE
CURVE
PROTRACTOR
TRIANGLE, 45°
TRIANGLE, 30° X 60°
LETTERING PEN
DRAWING BOARD
INK ERASER
SPONGE RUBBER
T SQUARE
PENCIL ERASER
STEEL ERASER
TRIANGULAR BOXWOOD SCALE 3/32, 3/16, 1/8, 1/4, 3/8, 1/2, 3/4, 1, 1 1/2, 3 IN. TO THE FOOT, 1/16 IN.
OR 1/8, 1/4, 3/8, 1/2, 3/4, 1, 1 1/2, 2, 3, 4 IN. TO THE FOOT, 1/16 IN.
TRIANGULAR BOXWOOD CHAIN SCALE: 10, 20, 30, 40, 50, 60 PARTS TO THE INCH
THUMB TACK
INDIA INK
ERASING SHIELD
PENCIL POINTER (FILE) AND TACK LIFTER

MECHANICAL DRAFTING

CHAPTER I

MATERIALS AND INSTRUMENTS

1. The selection of materials and instruments requires considerable knowledge and experience. The former is secured through the trade catalogs and by personal inspection at the dealer's; in the absence of the latter, competent advice should be sought. There is a great variety in the quality, style and size of drawing instruments; the outfit selected will be determined by the kind and amount of work to be done and the cost. Individual preference is also an important factor. The selection should be left to those who are responsible for the instruction and are familiar with local requirements.

The usual outfit is illustrated on Plate I. This may be increased as desired, and, if necessary, the bow set may be omitted, but these instruments are almost indispensable.

2. The drawing board should have at least one flat surface and a true working edge. One of the short edges is selected as a working edge and is used at the left. No other edge should be used, because the shrinkage of the wood causes the board to become "out of square."

3. The T square consists of a thin straightedge or *blade* to which is secured the *head*. The upper edge of the

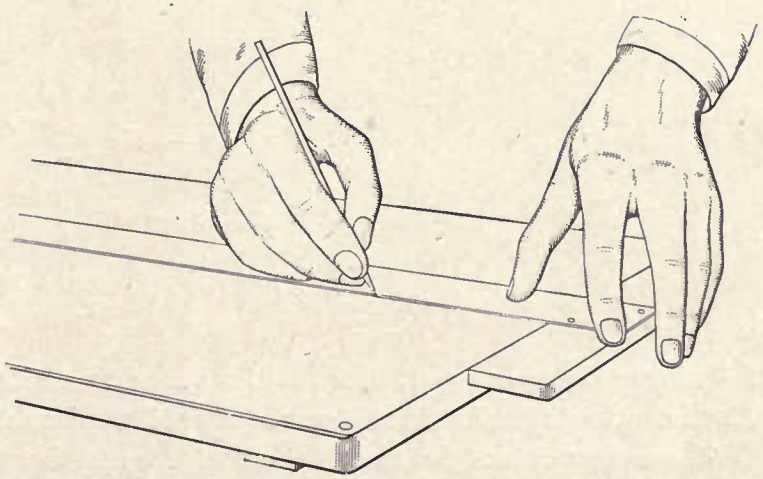


FIG. 1.—Using the T Square.

blade and the inside edge of the head must be straight. In use, the T square is held with the head firmly set against the working edge of the board and with the blade flat

against its face as in Fig. 1. Lines are drawn only on the upper edge, holding the pencil point close against it. Move the T square by sliding the head.

4. The triangles most frequently used are the 45° and the 30°–60°. All angles and edges should be true. The triangles are used for drawing vertical and inclined lines. For drawing vertical lines, the triangle is placed against the

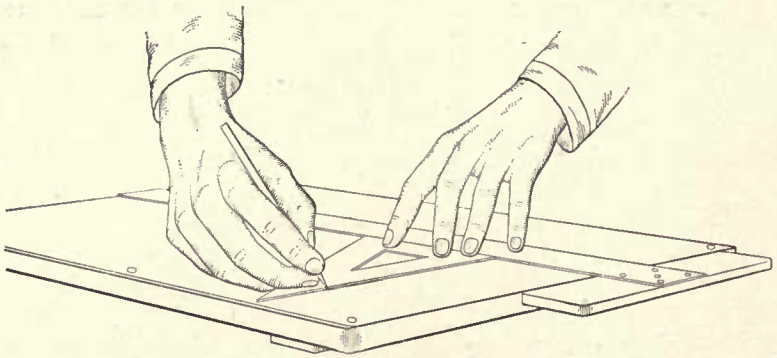


FIG. 2.—Using the Triangle.

T square as shown in Fig. 2. Inclined lines are drawn with the triangle resting against the T square or another triangle.

The corners of triangles easily get out of true and therefore the edges only should be used.

5. Testing for Accuracy. *Prove* the straightness of the left end of the drawing board, and of the upper edge of the blade and the inside edge of the head on the T square, by means of a straightedge. *Prove* the correctness of the triangles by drawing lines at 45° and 90° with a given line, then by reversing the position of the triangle note whether or not the edges now coincide with the test line. (See Fig. 3.) A steel protractor may be used to test the angles of 30° and 60°.

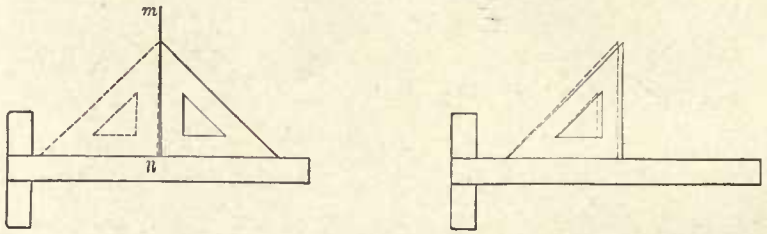


FIG. 3.—Proving the Triangles.

6. The irregular curve is used for drawing lines which are neither straight nor arcs of circles. Such lines are usually determined by a series of points through which a freehand curve is lightly penciled, after which it is made smooth by applying the *curve*. The curve is placed so that a portion of it coincides with the line and with the general direction of curvature. A part of the matched portion only is drawn, the curve then being shifted and matched again as suggested in Fig. 4. This operation is repeated until the whole line is smooth and continuous.

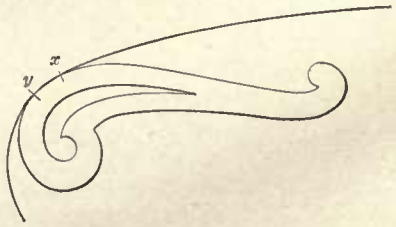


FIG. 4.—Using the Curve.

7. The scale is for laying off measurements. It is placed flat on the drawing with the zero mark exactly at the point. The required distance is then read off and indicated by a small dot, using a fine pencil point, in the manner shown in Fig. 5.

Successive dimensions should be laid off when possible without moving the scale. The edges of the scale should be protected from wear or damage, otherwise the marks or

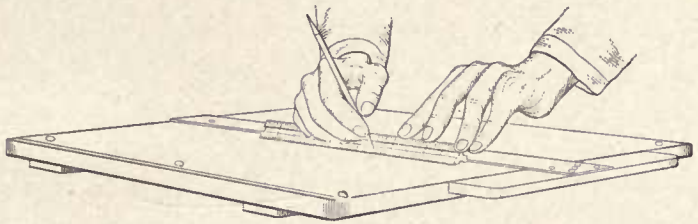


FIG. 5.—Using the Scale.

graduations will become indistinct. The accuracy of the scale may be proved by laying off several divisions, then reversing the scale to see if they coincide.

8. The compass consists of the following principal parts: *Head, legs,* and *lengthening bar.* The legs are designated according to use as "needle point," "pencil point," and "pen point."

Each leg is provided with a joint which enables a parallel adjustment to be made for large circles. The compass is adjusted by first inserting the pen leg, then the shoulder of the needle point is brought even with the pen point. The needle point should be left in this position permanently and the lead adjusted to it.

The lead used should not be softer than 4H and should be sharpened to a *chisel point.*

9. In use, the compass should be slightly inclined forward and rotated clockwise between the thumb and finger, the needle point being pressed into the paper sufficiently

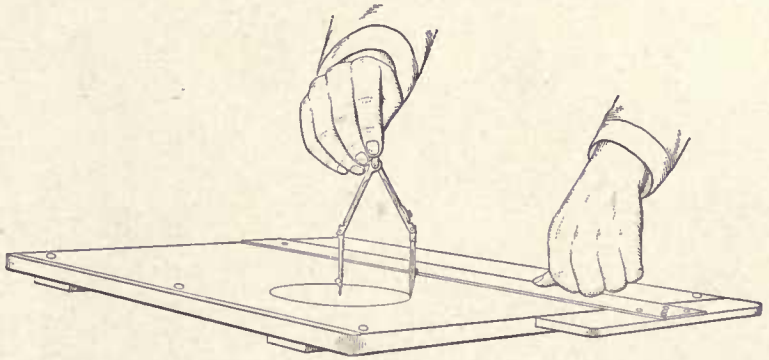


FIG. 6.—Using the Compass.

to hold firmly but not to punch a large hole in the paper. Fig. 6 will illustrate the method. A small freehand circle penciled around the hole assists one readily to pick up the center again. Concentric circles should be drawn beginning with the smallest, removing the compass from the paper for each change of radius. A circle should be drawn with one sweep of the compass; a second sweep will broaden the line. In drawing circles having a diameter greater than $1\frac{1}{2}''$, the

legs of the compass should be adjusted so that they are parallel. For arcs of large radius the lengthening bar is used; the marking point is moved with the right hand and the needle point is steadied with the left.

The beam compass is used for radii beyond the capacity of the ordinary compass with lengthening bar.

10. The dividers are used for spacing off equal distances and laying off measurements. The dividers are adjusted and

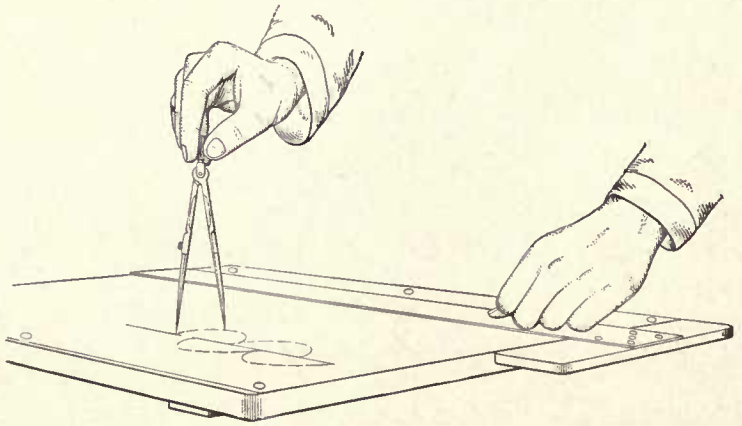


FIG. 7.—Using the Dividers.

manipulated with one hand. Fine adjustment is secured by using the "hair-spring." To lay off equal spaces, or to divide a distance into equal parts, the dividers are set roughly by guess. This distance is then stepped off by holding the instrument lightly between the thumb and finger and rotating it in opposite directions alternately. See Fig. 7. The dividers are readjusted if the space is not commensurate and the distance is stepped off again, the trial process being repeated until the divisions are equal. The trial points should not puncture the paper.

11. The bow-set consists of *bow-dividers, bow-pencil,* and *bow-pen.* They are intended to be used for small work; their construction, adjustment and use are similar to those of the larger instruments described above. The compasses are used for circles of less than $\frac{3}{4}''$ radius.

12. The ruling pen is one of the most important instruments of the set. It is essential that the condition and use of the pen be observed carefully. The points or "nibs" must be of equal length, rounded at the point as shown at (*a*), Fig. 8, and fairly sharp. The space between the nibs determines the width of the line and is regulated by the adjusting screw.

The pen is filled by flowing the ink between the nibs from the point of a quill; there must be no ink on the outside. Too much ink will result in a blot.

13. When in use both nibs should rest on the paper as shown at (*b*), Fig. 8, leaving a space between one nib and the T square or triangle. If only one nib touches the paper a ragged line or blot will result. The pen should be drawn from left to right and from bottom to top, inclining it slightly in the direction of movement, as shown at (*a*) Fig. 8 and in Fig. 9.

The pen should be pressed lightly against the ruler; varying the pressure will cause unevenness. Note that the hand is steadied and guided by the light touch of the fingers.

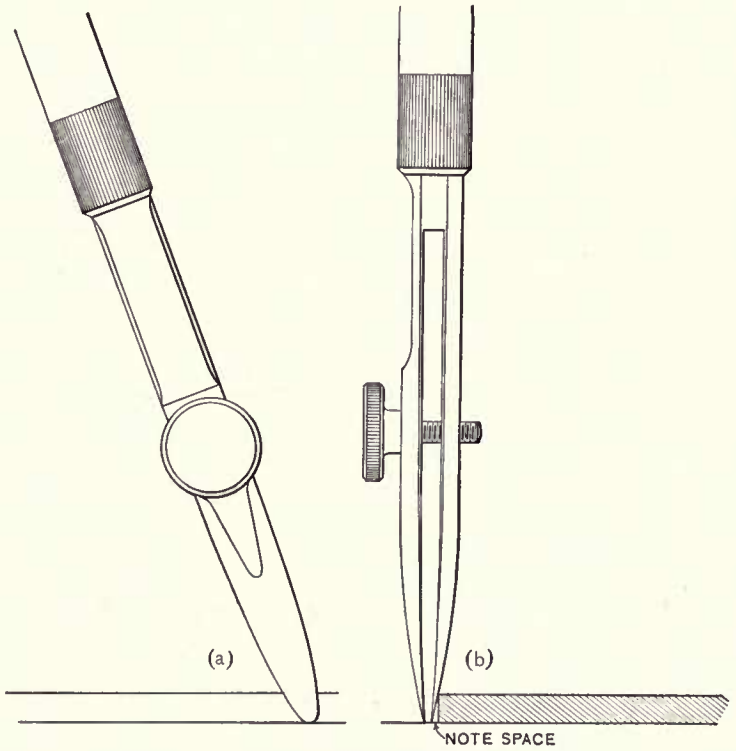


FIG. 8.—The Ruling Pen.

14. As the ink dries rapidly, the pen must be wiped frequently between the nibs. This should be done thoroughly with a piece of good linen. If ink is left in the pen it will corrode the steel.

The above instructions for the ruling pen apply to the compass pen also.

When the nibs of the pen become worn they must be resharpened. This requires experience, and competent advice should be sought before attempting it.

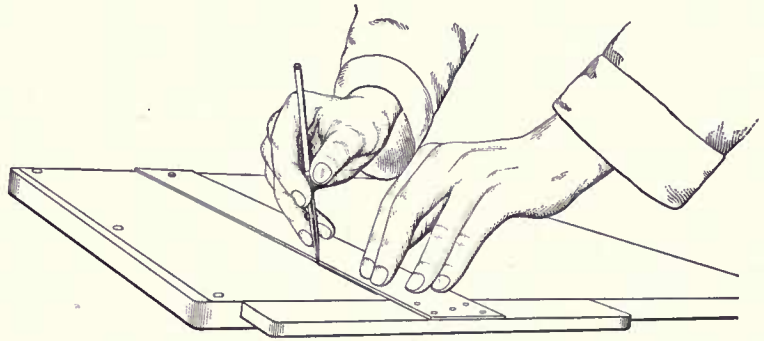


FIG. 9.—Using the Pen.

15. The protractor is used for laying off, or measuring, angles. When used, it is placed with its center at the vertex of the angle and the zero marks coinciding with one side, which should be extended for this purpose. The desired angle is laid off by making a dot with a fine pencil point at the required division and drawing a line through it to the vertex.

16. Care of Instruments. Keep the blade of the T square clean by occasionally sand-papering it lightly.

Triangles should be wiped off with a damp cloth. Pens should be wiped dry, using a piece of linen or chamois; ink should not be allowed to dry on. When not in use the pens should be left open.

Keep all instruments clean. They should be rubbed frequently with a chamois, and steel parts should be oiled occasionally.

17. Drawing paper is made in various grades, sizes, and shades. Good drawing paper is tough, strong, and will withstand considerable erasure.

For drawings that are to be inked, the surface of the paper should be fairly smooth and of a quality such that the ink will lie well upon it. Pencil drawings should be made on a paper having a hard surface with a "grain" which will take the pencil. The working surface of a paper is the one from which the "water-mark" is read, but the opposite side may be used.

In general white papers are used for drawings that are to be inked, and buff papers for pencil work that is to be traced.

18. The kind of paper to be used for drawing depends upon circumstances. If only one copy is needed, it may be made upon a light buff or white paper of good quality and inked directly upon the sheet. Usually several copies are required and the original is then made upon a buff detail paper, after which it is traced. From the tracing any number of blue prints may be made.

Tracings are generally made by inking the drawing on tracing cloth or linen. Transparent paper is sometimes used, and a soft pencil may be substituted for ink when the conditions do not require the more durable and sharper-lined tracing.

19. Bond paper of good texture and light weight is sometimes used, both for the original drawing and for the tracing. It has a good drawing surface and takes ink well.

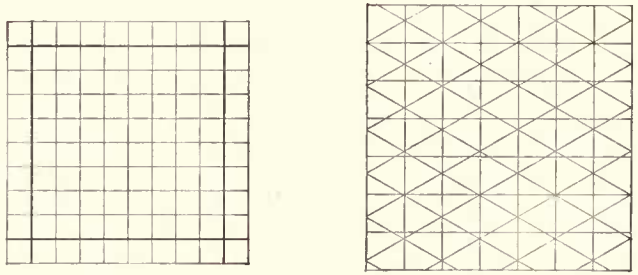


FIG. 10.—Cross-section Paper.

Blue prints may be made from bond paper, but this is greatly facilitated by first applying a commercial solution to render the paper more transparent. Other papers may be "transparentized" and printed from with success.

Cross-section paper should be used for sketching. It may also be used for printing as directed above for bond paper. It may be had in 8x8 and 10x10 divisions to the inch, also in "isometric" and other rulings. See Fig. 10.

20. Pencils of various qualities and degrees of hardness are used in drafting. The lead should be smooth, not gritty, and of a hardness suited to the paper. The grade selected should produce a fine, light line on the surface of the paper, which may be erased without leaving a trace. A 4H or 6H grade for lining and a 2H or 4H grade for lettering are commonly used. Draftsmen usually prefer a pencil of hexagonal shape, as it is not so liable to roll.

21. The harder or **drawing pencil** is usually sharpened on both ends—one to a round point and the other to a

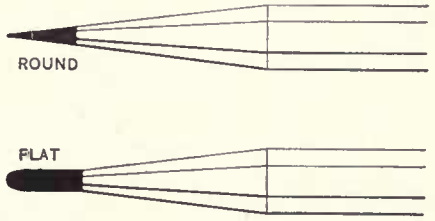


FIG. 11.—Pencil Points.

flat point, as shown in Fig. 11. The round point is used for locating points and the flat point for lining. The **softer pencil** is used for lettering and sketching and is sharpened on one end to a round point. The points should be kept sharp by frequent applications to the sand-paper or file.

22. Erasers are of great variety in quality, grade, shape and size. For pencil lines a soft, velvet rubber may be used. Ink lines require a hard rubber. The best quality should always be used, as a poor eraser will spoil the drawing. The eraser should be kept clean and when it becomes old and hard it is no longer fit for use. Erasers should be used only when necessary, and then lightly, to avoid injuring the surface of the drawing.

23. If the student is careful to see that hands and drawing tools are clean, that he understands the arrangement and plan of procedure before he begins, and is careful to employ only fine, light lines, very little erasing will be required. The practice of smearing a drawing and then scrubbing it at the end should be discouraged. Some teachers require drawings to be made over again that show erasure.

24. Drawing inks are usually prepared and come in bottles with a quill *filler* attached to the cork. A good India ink should flow freely, dry quickly, and be waterproof. The bottle must be kept corked to prevent evaporation. If the ink is too thick, a few drops of dilute ammonia or distilled water may be added.

Red ink is sometimes used for center and dimension lines, and blue for construction lines; the objection to their use is that they fade.

25. Miscellaneous Articles. Thumb tacks should have small, flat heads, and short, tapering pins. They should be pressed in flush with the board. Some prefer to use 1 oz. copper or iron tacks.

A pencil pointer of sand-paper or a flat file should always be ready and used frequently. A combination file and tack-

lifter is a useful implement. Keep the dust from the drawing, tools, and hands.

A pen-holder of medium large diameter, preferably with a cork stock, should be provided.

The pen-point for lettering should glide smoothly and make a line of uniform width without pressure sufficient to open the point. The ball-pointed pen is popular and other styles have rounded points. The student should select his own pen and then take good care of it.

A pen-wiper of linen is very good; pieces of tracing cloth from which the "sizing" has been soaked make excellent pen wipers.

A chamois for wiping the instruments is essential.

A blotter should be at hand in case of need, but it is not to be used on inked lines.

CHAPTER II

PRINCIPLES OF DRAFTING

26. The fundamental object of mechanical drawing is to convey information for purposes of construction. It is intended to be used in the place of oral or written expression and therefore it should be regarded as a language, having as such well-defined forms, usages, and conventions. The basis of this universal language is the line, and in its various forms the line may be regarded as constituting the alphabet of mechanical drawing.

27. The lines of a drawing are conventional. The outlines of the object are represented by lines of greater width; **full lines** if the edges are visible, and **dash lines** if invisible. **Auxiliary lines** are of a lesser width and include all except outlines. They are *center*, *dimension*, *extension*, *section*, and *construction lines*. The character and uses of the various lines are shown in Figs. 12 and 13.

Colored inks are frequently used to denote auxiliary lines, which should then be drawn full instead of broken.

28. To facilitate the reading of the drawing it should be strong in **contrasts,** which effect is secured, partially, by varying the widths of the lines. There is no absolute standard for this, but the relation of the lines should be observed. The outlines of the object shown should always be the most prominent feature of the drawing and, therefore, the lines representing the visible and invisible edges should be drawn strong and bold.

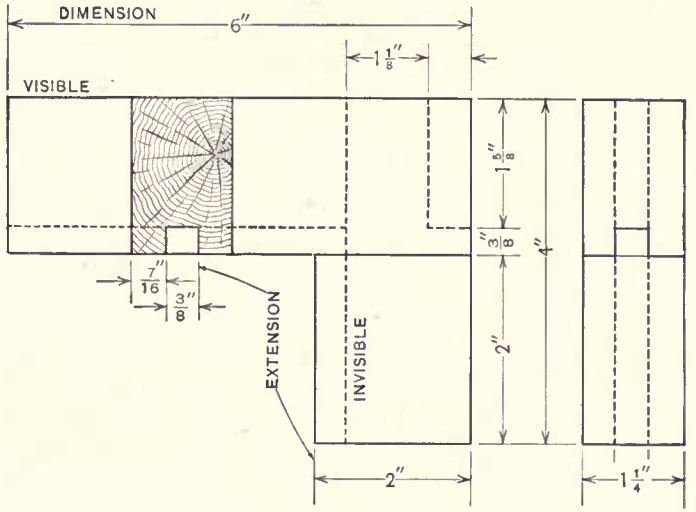


FIG. 12.—Illustrating the Alphabet.

29. Lettering is very important, and if not well done it

detracts from the appearance of the drawing. Skill in lettering may be secured by the application of a few simple

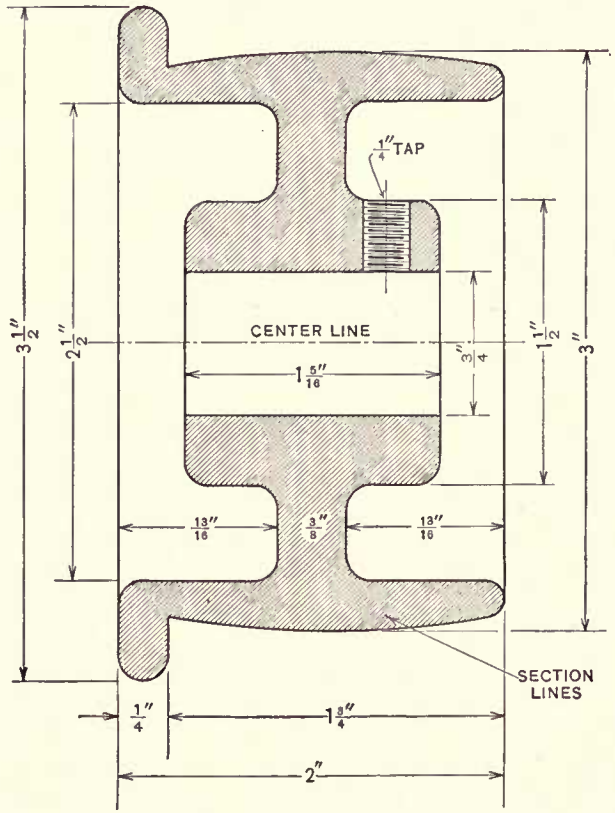


FIG. 13.—Illustrating the Alphabet.

principles. In the first place the form and proportions of letters should be carefully noted. The analysis of the alphabet shown on Plate II will assist to an understanding of these features. The height and width of letters should be proportional.

In forming letters it should be observed that their proportions are determined by the *space* which the boundaries, real or imaginary, inclose. This will be understood by referring to Fig. 14 and noting the relative positions of the "cross-bar." When the cross-bar is placed too low, the letter appears inverted or top-heavy. The greater space should be below the bar, but the spaces above and below

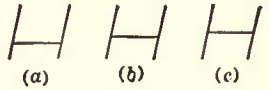


FIG. 14.—Effect of Varying Height of Cross-bar.

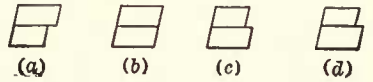


FIG. 15.—Effect of Increasing Space Below Cross-bar.

should be very nearly equal. In a similar manner, by varying the length of the top or bottom bar, the letter may be changed from an unstable to a stable appearance as shown in Fig. 15. In (*d*) the cross-bar is also raised a trifle above the center.

30. Letters should be spaced so as to equalize the areas between them, and not at a fixed distance. Words are made more prominent by increasing the spaces. Letters should be made full-bodied and kept rather close together; words should be kept well apart.

Letters may be slanted or not according to taste, but in every case the aim should be to secure uniformity and

ABCDEFGHIJKLMNOPQ
RSTUVWXYZ
1234567890 & $3\frac{5}{8}$
abcdefghijklmnopqrstuvwxyz

ABCDEFGHIJKLMNOPQR
STUVWXYZ 1234567890
abcdefghijklmnopqrst
uvwxyz

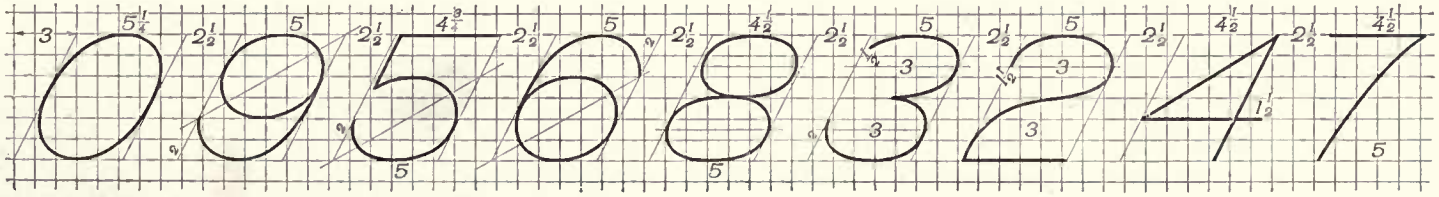
ABCDEFGHIJKLMNOPQ
RSTUVWXYZ
1234567890 & $3\frac{5}{8}$
abcdefghijklmnopqrstuvwxyz

NOTE: The ferm, proportion, and spacing of letters should be studied analytically. This may be done to advantage on cross-section paper in the manner indicated.

Small letters should be made two-thirds the height of capitals.

The slant should be uniform.

Take pains and persist; proficieney is attained in no other way. Skill will come with PRACTICE.



simplicity. The angle of slant is 60° to 70°; a natural slope is approximately 65°.

Small letters should be two-thirds the height of capitals; for notes and general purposes $\frac{1}{8}''$ and $\frac{3}{16}''$ respectively, are recommended.

31. All lettering on drawings should be done freehand and light guide lines should be ruled to secure evenness. A sense of proportion is of great importance in lettering, and it may be acquired by forming the habit of critical observation.

Use a medium, H or 2H, pencil, and a ball-pointed pen. Everything depends upon *practice*.

32. Penciling is of the greatest importance in securing good workmanship. The beginner generally makes the mistake of using too soft a pencil, which produces a heavy line, or of bearing on too much with a hard pencil, which cuts grooves into the paper. The pencil should be adapted to the paper used and fine, sharp lines should be drawn lightly but clearly.

33. Horizontal lines are drawn with the upper edge of the T square from left to right. Points for such lines should be located at the left.

Vertical and inclined lines are drawn with a triangle and usually from the bottom toward the top. Points for such lines should be located at the bottom.

34. The preparation for drawing includes tacking the paper on the board and drawing the margin and trimming lines. This is illustrated on Plate III. The dimensions indicated may be varied to suit. The purpose of a **scheming sheet** is to plan in advance the layout of a drawing so as to secure a balanced arrangement and to avoid crowding. The rectangles are drawn to scale and indicate the approximate size and location of the views. This is done on note or trial paper.

The views should be located in such a manner that the space on the drawing sheet is well occupied without crowding. A well-balanced effect adds to the appearance of a drawing.

The figures within the circles indicate the individual drawings of the separate parts of an object. They are *identification marks* and should appear also in the B.M. (Bill of Material) under the proper heading.

Sheets are laid out to suit conditions, as follows:

(*a*) Assembly; a drawing showing the object as a whole.

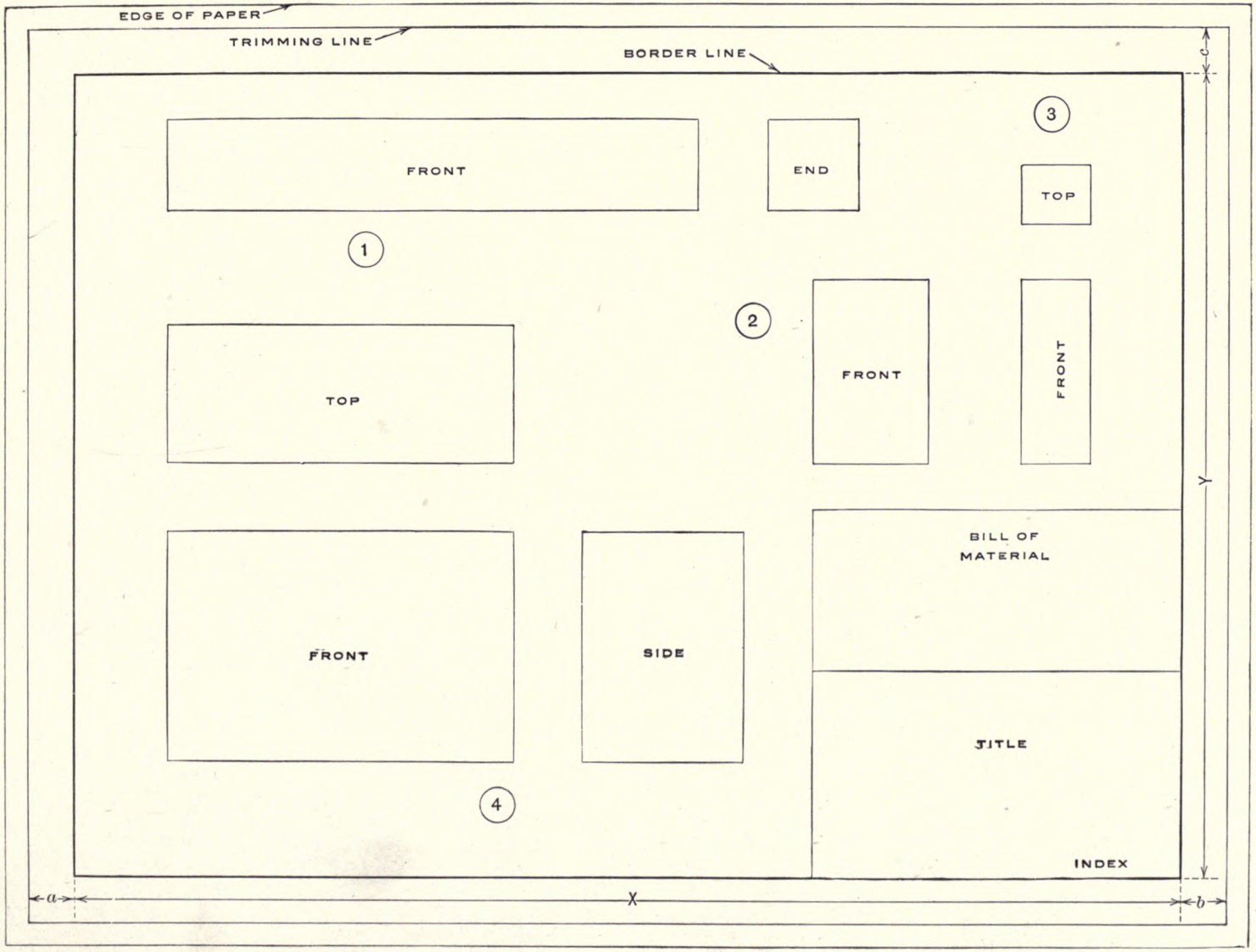
(*b*) Detail; a drawing showing a single part of the object.

(*c*) A group of related details, i. e., of the same material or of adjoining parts.

(*d*) Miscellaneous details.

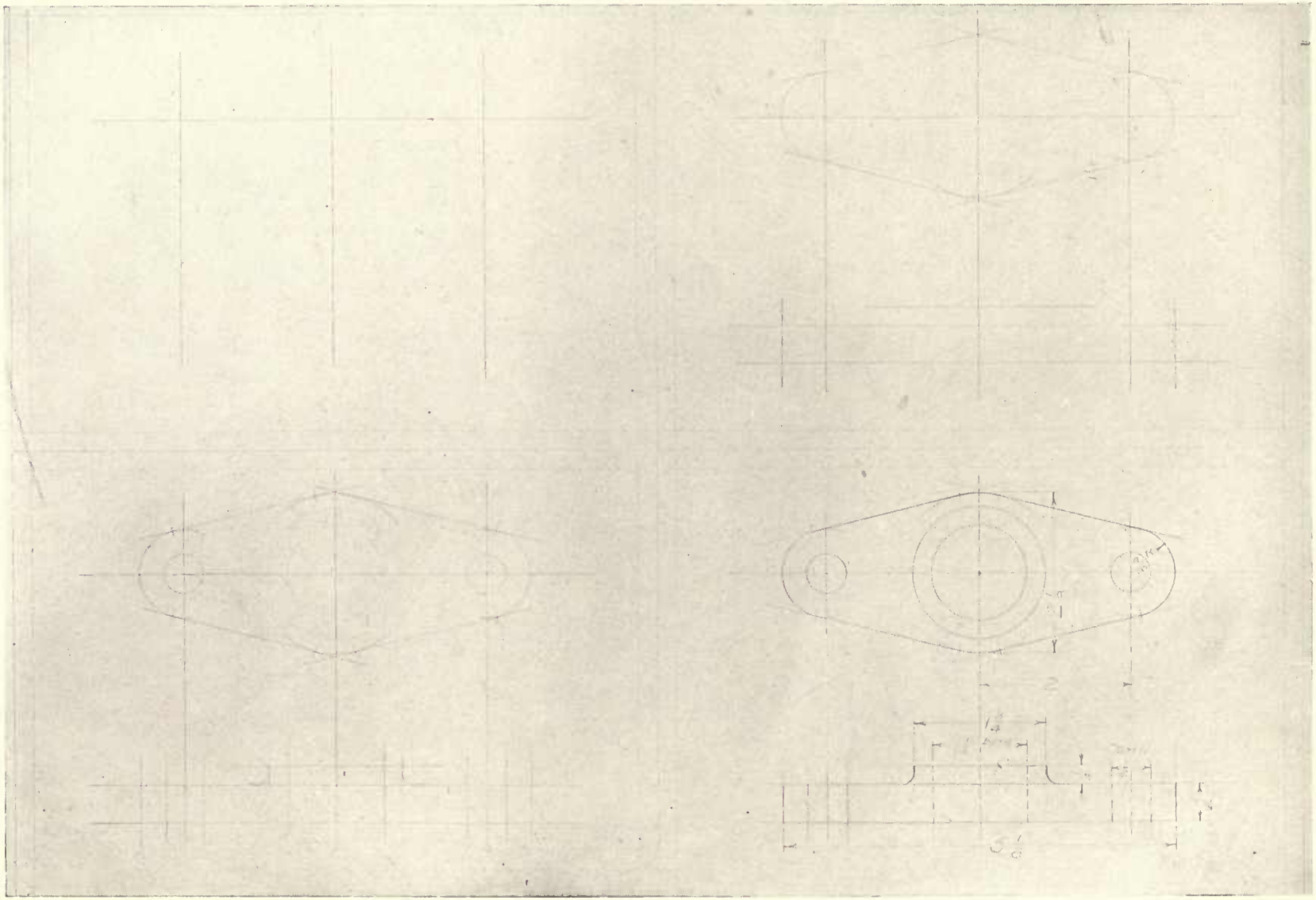
(*e*) Assembly and details.

35. The layout of a drawing includes the following steps in their order: (*a*) Draw the margin lines; (*b*) block in a space for the title; (*c*) draw the center lines of the views; (*d*) draw the outlines of the views. Some draftsmen do not use margin lines.


EDGE OF PAPER
TRIMMING LINE
BORDER LINE
c
3
FRONT
END
TOP
1
2
TOP
FRONT
FRONT
Y
BILL OF MATERIAL
FRONT
SIDE
JITLE
4
INDEX
a
X
b

(*a*) Main Center Lines.

(*b*) Principal Outlines.



(*c*) Details.

(*d*) Dimensions, Notes, etc.; Outlines Darkened.

The outlines of the views should be blocked in very lightly, using a hard pencil and a fine line. Do not measure off the corners, but draw the lines of indefinite length and project them to all views. This is a time-saver. See Plate IV.

Prove the correctness of the layout.

36. The details should be drawn after the outlines are all in. Next, draw the dimension and extension lines, arrow points, figures, notes, and title in the order named.

Each detail should be drawn complete in all views before proceeding with the others. It is not good practice to complete one view before beginning others.

It is customary to draw first all center lines full and afterward to retrace them. This saves time in blocking-in.

37. There is a great variety in the form and location of **titles,** also in numbering or **indexing** drawings. Suggestions are offered on Plate V.

The usual location for the title is the lower right-hand corner, as this position facilitates filing.

A bill of material, or stock bill, if it is placed on the sheet, should be located directly above the title.

38. The final drawing is usually in ink and the pencil drawing should be considered as temporary in character. The pencil drawing should be complete and the character of all lines distinctive, so that any competent person may ink or trace it, but no time should be spent unnecessarily.

If the drawing is to be *traced* the outlines should be emphasized with a pencil of H or HH grade.

All drawings should be carefully checked for error.

39. The inking of a drawing should not be proceeded with until the penciling is finished. If the surface of the drawing has been damaged by erasure, poor results will be obtained. The surface must be free from dust.

The inking should proceed systematically. Having adjusted the pen to a given type of line, begin at the top and ink all the horizontal lines of that type; next, the vertical lines, beginning at the left; finally, ink the inclined lines. Always work away from the fresh ink and do not use a blotter on the lines. Try to secure uniformity and accurate corners, joints and tangents. If a line is imperfect, ascertain the fault and apply the remedy.

40. If **erasure** is necessary it should be done with great care, using light pressure, so as to remove the *ink only* and not damage the surface of the drawing. An erasing shield will assist in this respect.

Practice inking on a separate sheet before attempting it on the drawing.

Shake the bottle of ink before filling the pen; test the pen after filling to see that the ink flows freely and that the line is of the proper width.

Ink the lines in the following order: Center, circles, arcs, curves, straight, dimension, figures, section, lettering. See Fig. 16.

PLOT
OF SURVEY OF
THE MAPLES FARM
TOWN OF NEWSTEAD
ERIE CO. N.Y.
SCALE 1"=200 Ft.
DRAWN BY DATE

~FIRST·FLOOR·PLAN~
Scale $\frac{1}{4}$"=1 foot

·RESIDENCE·FOR·
·HENRY P. SMITH·
652 GREENWOOD·AVENUE
BOSTON · MASS.

RALPH PARRIS·ARCHITECT
390 FIFTH AV.·NEW YORK·

STOCK BILL AND ESTIMATE

WORKBENCH

QUANTITY	SIZE OF STOCK	MATERIAL	COST	VALUE
30 FT.	1 x 12 x 8	N.C.P. "B" d.s.	$45 M	$1.35
34 "	1 x 12 x 8	" "	" "	1.53
8 "	2 x 4 x 12	" COM.	$27 "	.22
4 "	2 x 8 x 3	OAK "B"	$50 "	.20
6 "	$\frac{1}{2}$ x 9	W.W.	$70 "	.42
		COST OF LUMBER		$3.72
		HAROWARE		
1	$1\frac{1}{4}$ VISE SCREW		.60¢	0.60
2 LBS.	8d NAILS, COMMON		.03$\frac{1}{2}$¢	0.07
2 LBS.	" " CASING		.03$\frac{1}{2}$¢	0.07
		COST OF HARDWARE		0.74
		MISCELLANEOUS		
$\frac{1}{2}$ GAL.	READY MIXED PAINT		$1.60	.80
		TOTAL COST OF MATERIALS		$5.26
	LABOR TO BE DONE BY SELF			

BILL OF MATERIAL

FIG.	NAME	NO. REQ	MAT'L	REMARKS.
A	BED.	1	C.I.	PAT. Nº 1.

DETAILS
7" HAND LATHE
STUYVESANT HIGH SCHOOL
NEW YORK CITY
SCALE 12"=12"

DATE NAME.
APPROVED

41. Tracings are made by inking the drawing on transparent paper or cloth. The object of this is to preserve the original and also to provide additional copies quickly and cheaply by means of blue-prints. (See Chap. X.)

42. Tracing cloth having one side glazed and the other dull is generally preferred. The beginner should always use the glazed side for inking, as the inevitable mistakes are

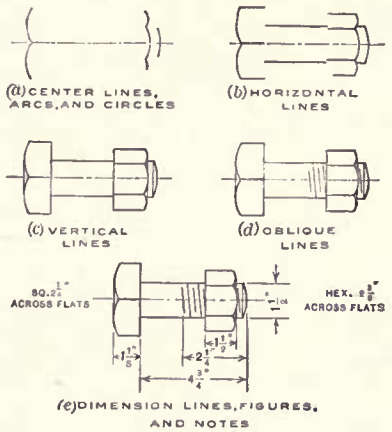

(a) CENTER LINES, ARCS, AND CIRCLES
(b) HORIZONTAL LINES
(c) VERTICAL LINES
(d) OBLIQUE LINES
SQ. 2" ACROSS FLATS
HEX. 2" ACROSS FLATS
(e) DIMENSION LINES, FIGURES, AND NOTES

FIG. 16.—Order of Inking.

more easily erased. The cloth is prepared by tacking it over the drawing, taut and smooth. Rub the surface with powdered chalk to take off the oil and clean it thoroughly. Do not put water on the cloth or handle it with moist hands; it may be wiped off with benzine or gasolene.

The moisture in the air will cause the tracing cloth to swell and shrink as conditions vary. It is therefore necessary to trace only a part of the drawing at a time, protecting the remainder by a paper tacked over it. The whole should be covered with a cloth over night.

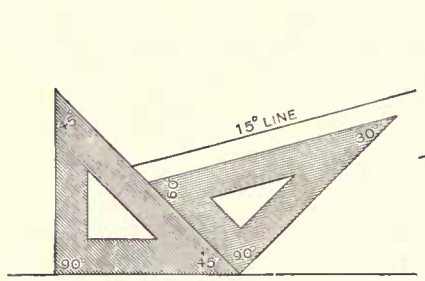
43. In general the directions previously given for inking should be followed. The beginner should not attempt to use a steel point for erasing; some do not use it at all. An erased surface should be rubbed with a piece of soap-stone before it is again inked.

Instead of using lines to indicate a sectioned surface, some draftsmen darken the area with a soft pencil or with dilute ink applied with a brush to the dull side of the cloth.

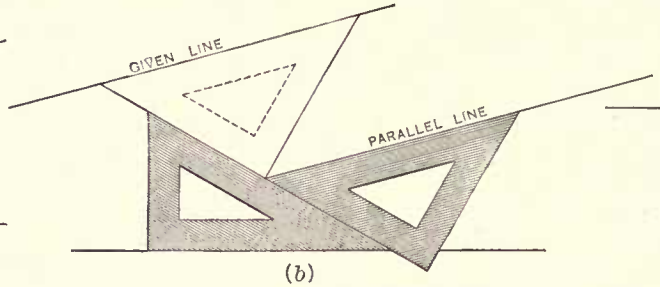
44. Geometrical constructions are drawn by means of the T square and triangles as far as possible. Angles of 15°, 30°, 45°, 60°, 75°, and 90° may be drawn, as well as parallels and perpendiculars, by using these tools singly or in combination; also they are used to draw the equilateral triangle, square, hexagon, octagon, and diagonals, as shown on Plate VI. Circles may be divided, by using the T square and triangles, into 2, 3, 4, 6, 8, 12 and 24 parts. Other constructions, when required, may be obtained from any text on geometry.

45. Drafting technic depends upon knowledge and skill. If it is to be acquired, great attention must be paid to details. Neatness and accuracy are absolutely essential. Slovenly work should not be tolerated under any circumstances.

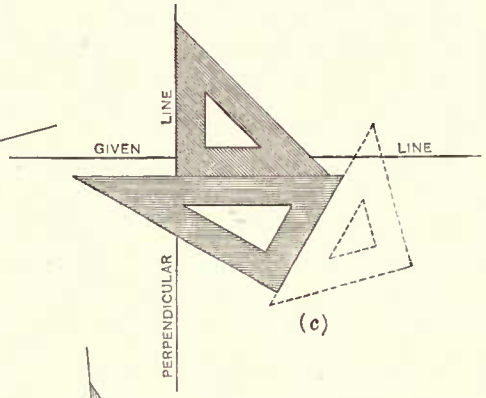
Neatness relates to the general appearance of the drawing, and includes erasures, blots, finger-marks and tears;



(a)



(b)



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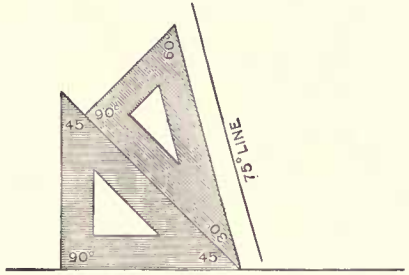
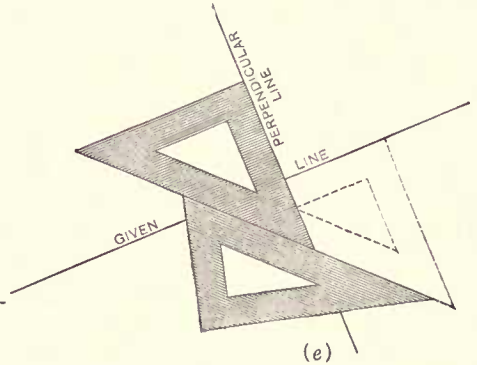
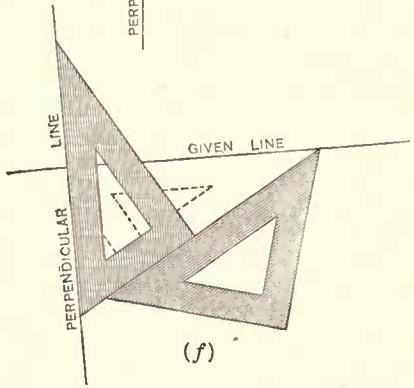


(d)

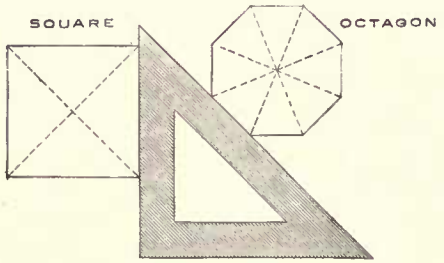


(e)



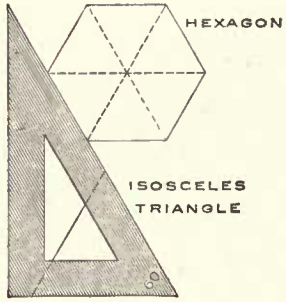
(f)

NOTE: FIRST POSITION OF TRIANGLE IS SHOWN BY DOTTED LINES.



(g)

(h)



(k)

also evenness of lines, shape and slant of letters, and balanced arrangement of the drawing.

Accuracy means exactness in laying off measurements and subdividing lines, in making intersections and connections, in laying off angles, in drawing lines, perpendiculars, parallels, and tangents, and in locating centers and joining arcs.

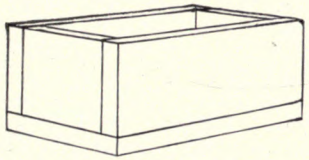


FIG. 17.—Perspective Drawing of a Box.

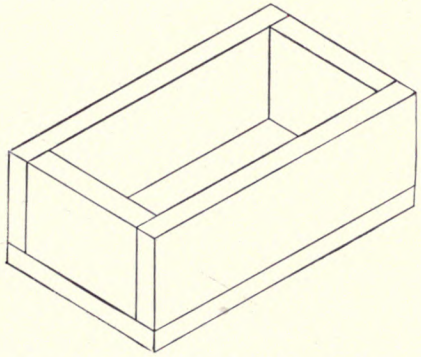


FIG. 18.—Isometric Drawing of a Box.

46. It is bad practice

To drop the T square, scale, or other tools on the floor.

To use the triangles or points of instruments to pry out tacks.

To use the scale as a straightedge.

To hammer in thumb-tacks with the T square or any other tool.

To use the upper edge of the T square as a guide for a knife.

To hold the pen over the drawing while filling.

To leave the cork out of the ink bottle.

To use the points of instruments to bore or ream holes.

To leave the pens and bow instruments screwed up tightly.

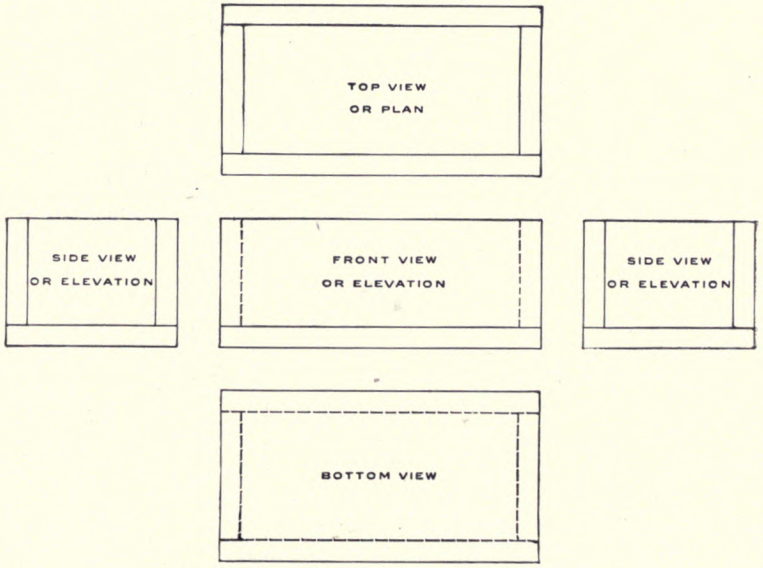


FIG. 19.—Projection Drawing of a Box.

To put away instruments without cleaning.

To begin work without first dusting off the table and tools.

47. Kinds of Drawings. (*a*) **A representative or pictorial drawing** is one that shows an object as it appears when viewed from a point from which two or more of the

faces or sides of the object are seen. The drawing of the box in Fig. 17 is of this type. The parallel edges appear to vanish and to meet at a distant point. This is also called a **perspective drawing.**

(*b*) **An isometric drawing** is similar to a perspective but the parallel edges are drawn actually parallel and not to a vanishing point as in perspective, see Fig. 18.

(*c*) **A projection drawing,** so called, represents each view or face of the object separately, as shown in Fig. 19. The broken lines represent edges that are hidden or invisible.

48. The arrangement of views for a projection drawing should be carefully noted. With respect to the front view, the top view is placed above, the right-side view to the right, the left-side view to the left, and the bottom view below. The bottom view is seldom used, and when the side views are alike one should be omitted. The back view is not usually required, but, if drawn, it should be placed on a line with the front view and to the right or left of the side view respectively. The above arrangement of views is in accordance with "third angle" projection, which is generally used in practical work. It is explained and demonstrated in the following paragraphs.

CHAPTER III

GEOMETRY OF DRAWING

Orthographic Projection

49. Geometry has many applications in the practice of mechanical drawing. Ordinary constructions, such as drawing a perpendicular, parallel, or tangent, are accomplished by the use of the T square and triangles as explained in Section 44. Constructions which involve a solution, such as bisecting a line, or drawing a circle through three given points, properly belong to the problems and applications of mathematical geometry and should be studied in connection with that subject.

50. There are, however, certain **mathematical curves** which are required in the solution of drawing problems, such as, the *ellipse, helix, involute,* and *cycloid.* These can be studied to the best advantage in connection with their applications and, as the last two of them are related to the more advanced phases of the subject, they are omitted here. The first two will be found in connection with the problems to which they relate.

51. Orthographic projection is the foundation of mechanical drawing. An understanding of its principles and how they are applied is of great value in making and interpreting drawings.

A projection is a view or picture upon a transparent screen. Rays of light from a stereopticon pass through the lantern slide, travel in straight lines, and form an image or

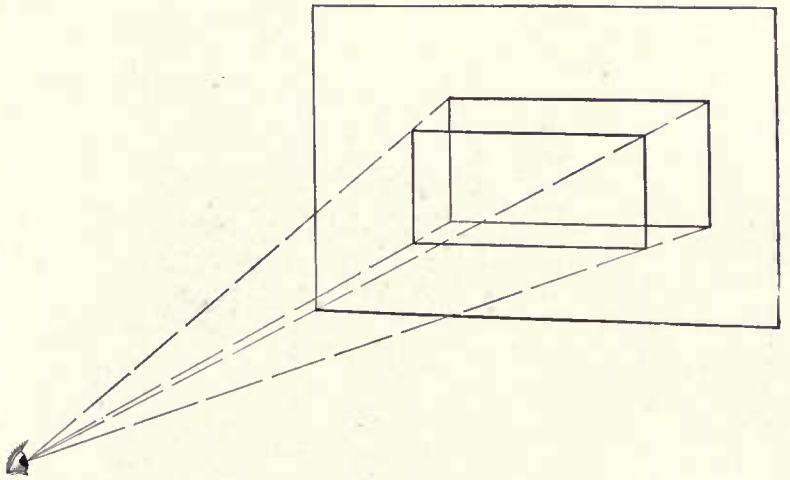


FIG. 20.—Perspective Projection or View.

projection upon the screen. Let a pane of glass be held in front of a thin object and from each corner or point imagine a ray or line of light to pierce the glass and travel to the eye. Join the points where the rays pierce the glass with lines

and the result will be a picture, or view, or projection of the object as shown in Fig. 20.

If the rays are made to fall upon the glass perpendicularly instead of obliquely, the result will be *a view or projection of the object in its actual form and size*, as shown in Fig. 21,

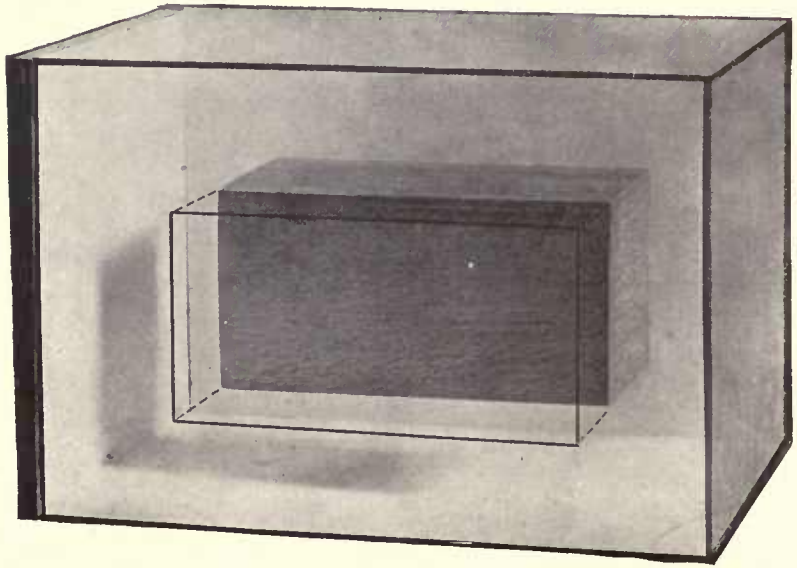


FIG. 21.—Projection of Object upon a Plane.

instead of being reduced or foreshortened as in Fig. 20. This is the *characteristic principle* of orthographic projection.

52. An orthographic projection is a view that shows the actual form and size of an object. It represents the object as it really is and not as it appears.

A top view or projection may be obtained by placing the glass horizontally over the top, and similarly, a side view may be obtained by placing it vertically at the side as shown in Figs. 22 and 23.

It should be observed that, in the above discussion, the

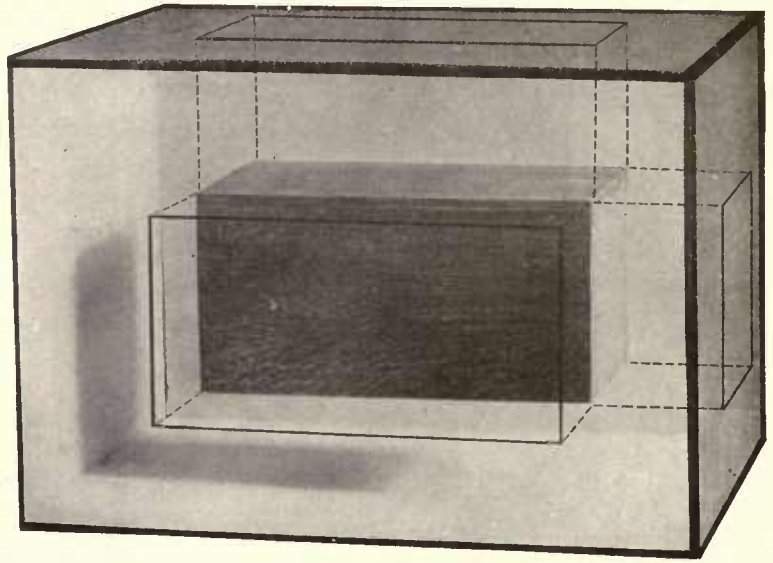


FIG. 22.—Projections of Object upon three Planes.

object is placed in such a position that its faces are parallel to the panes of glass and that only in this position are the projections of actual size and shape. If the object were turned so that the faces were not parallel, the projections would correspondingly represent the faces as being shorter, or foreshortened.

53. The panes of glass correspond to the **planes of projection.** They are known as the front (V), top (H), and side or profile (P); they are placed at right angles to each other. The intersections of these planes are called **traces.** The intersection of H and V is also known as the **ground line.** The object as shown in Fig. 22 is represented as being

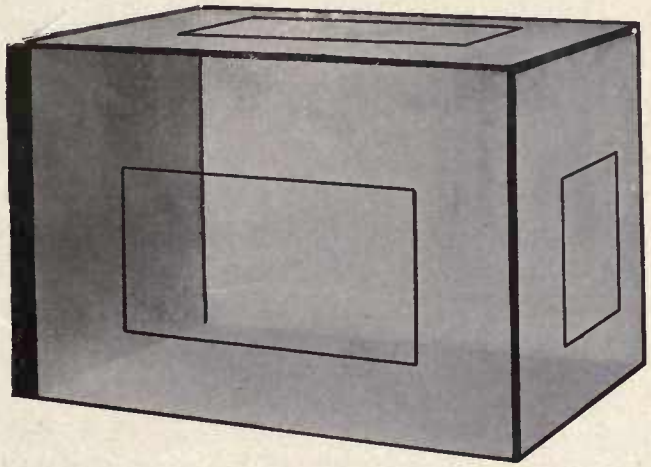


FIG. 23.—Projections of Object upon three Planes—Object removed.

placed in a box or space having *three dimensions.* In making drawings on a board it is possible to work in only *two dimensions,* therefore the top and profile planes are swung about their traces until they are all in one plane (V) as shown in Fig. 24.

54. **A projection drawing** of the same object shown previously may be seen in Fig. 25. The front, top, and side views are the projections of the corresponding faces of the object upon their respective planes, as shown in Fig. 22, which are swung into one plane for convenience in working on the drawing board.

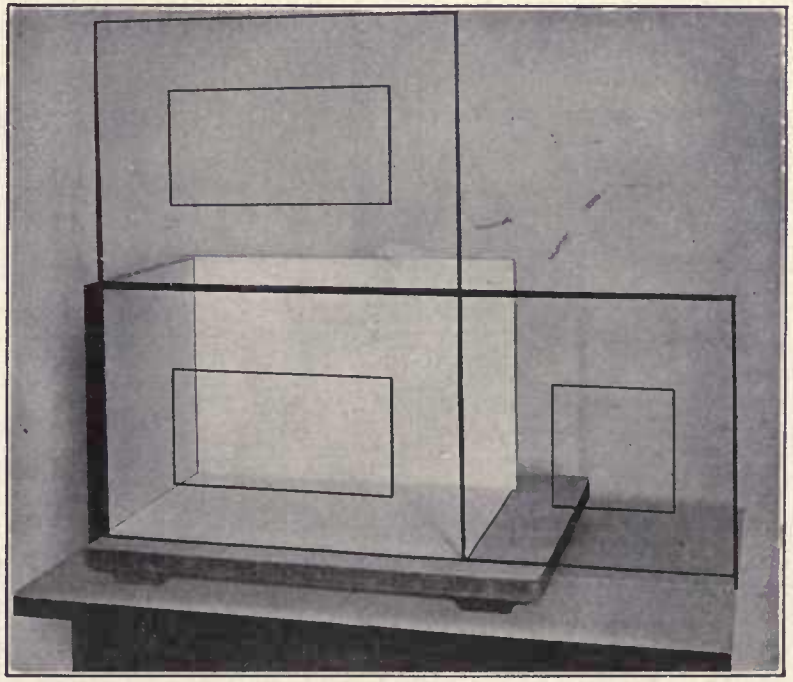


FIG. 24.—Planes Revolved into One Plane.

It will be seen that each corner of the object is represented by three points in the drawing—one point in each view. In other words every point on the object has a corresponding point or projection on each plane; these are

denoted the V, H, and P projections of the point, the letters referring to the respective planes. For example, the projections of the point C are C_v, C_h, and C_p.

Where two points are located in the same perpendicular, they project into one common point, as shown in Fig. 25;

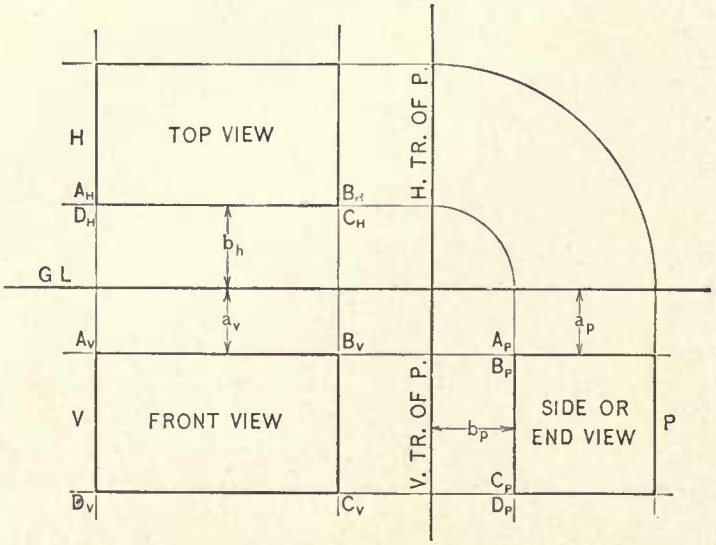


FIG. 25.—Drawing of Object in Orthographic Projection.

the points B and C of the front view project into the one point BC in the top view.

55. The traces are designated as GL (ground line), which is the line of intersection of the H and V planes; V Tr. of P (vertical trace of profile plane), which is the intersection of the V and P planes; and H Tr. of P (horizontal trace of profile plane), which is the intersection of the H and P planes.

The lines which project the points on the object to the planes are called **projection lines** or **projectors**; these lines are always perpendicular to the planes of projection in space, therefore on the drawing they will always be perpendicular or parallel to the traces.

56. It is evident that the top view is directly above the front view; that the side view is in the same horizontal line with the front view; that the front and side views are the same height; that the front and top views are the same length; and that the top and side views are the same width.

A thorough understanding of the fundamental principles is absolutely essential in solving the problems in projection. The student should therefore be familiar with the following facts:

(*a*) *The distances* a_v *and* a_p *are the same, or that both the front and side projections of a point are in a horizontal line. Similarly the front and top projections are in a vertical line.*

(*b*) *The distances* b_h *and* b_p *are the same and denote the distance that the object is placed back of the front plane.*

(*c*) *The front view* ABCD *projects into a single line* AD–BC *in the top view, and* AB–CD *in the side view.*

(*d*) *A line projects into a point, a shorter line, or its true length, according to whether it is perpendicular, oblique, or parallel to a plane of projection.*

(*e*) *A surface projects into a line or figure, according to whether it is perpendicular or oblique to a plane of projection; if parallel to a plane of projection it is projected on that plane in its true shape and size.*

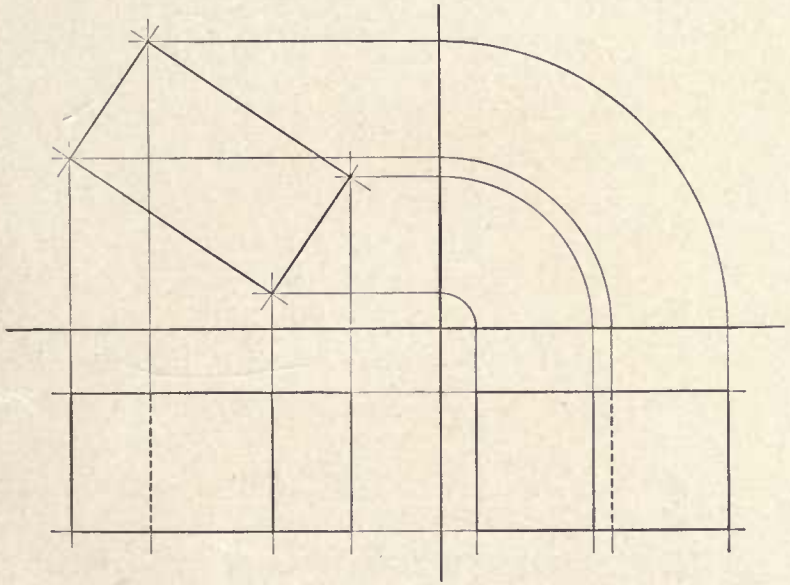


FIG. 26.—Projections of Object Oblique to V and P.

57. In the previous discussion of this subject it was assumed that the faces of the object were parallel to the planes of projection. In Fig. 26 the object is placed so that the front and side faces are not parallel to the planes. As the top face is still parallel to H, the top view is the same as before except that it is turned into an oblique position, but the front and side views are now longer than before. From this it is seen that placing an object obliquely to a plane changes the projection upon that plane. This is shown also in Fig. 27, where the object has been placed

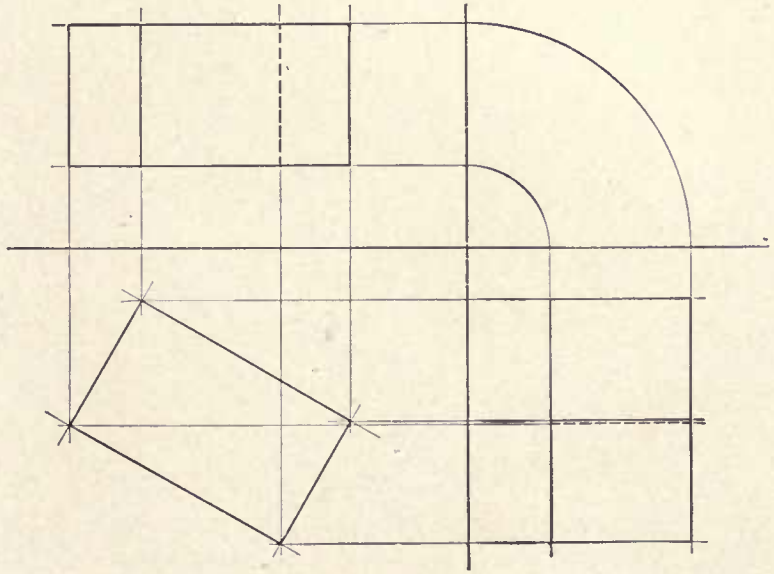


FIG. 27.—Projections of Object Oblique to H and P.

obliquely to H and P, its projections upon those planes being changed. In Fig. 28 the object is oblique to H and V, and the projections upon those planes are correspondingly changed.

58. The turning of the object into a position such that some of its faces are not parallel to the planes of projection

may be considered as the revolving of the object about an imaginary axis. In Fig. 26 the object was turned around on its base, or revolved about a vertical axis perpendicular

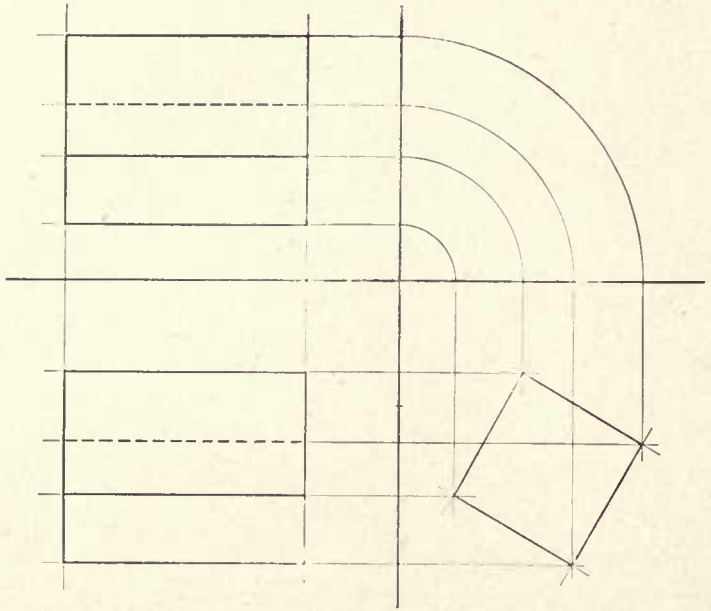


FIG. 28.—Projections of Object Oblique to H and V.

to H. In Fig. 27 the object was revolved about an axis perpendicular to V.

When the object shown in Fig. 25 is turned on its base or, in other words, revolved about a vertical axis, it is seen that:

(*f*) *The distance a is the same as before, and the height also remains unchanged; but the lengths of the front and side views become greater.*

(*g*) *The position of the top view is changed, but its size and shape remain unchanged.*

These facts may be expressed tersely thus:

Distances parallel to the axis of revolution remain unchanged.

The view which lies in the plane perpendicular to the axis of revolution remains unchanged.

The principles of projection, as stated above, also apply when the object is revolved about an axis perpendicular to V or P.

59. From what has been stated it should be observed that in revolving about an axis there is always an unchanged view. Therefore in solving problems in projection *the unchanged view is the one to be drawn first,* the other views being then projected from it. After drawing the unchanged view and projecting it to the other views, *the unchanged dimensions are then laid off* and the remaining views are blocked in.

If the points to be projected are numbered or lettered, as for example 1_v, 1_h, 1_p, denoting the respective projections, the work of tracing the projectors and determining the intersections will be made much easier. It is also helpful to remember that when an object is revolved about an axis its various points describe circles which lie in parallel planes whose distances apart do not change. This may be demonstrated by placing chalk marks on a top and then causing it to spin.

60. The revolutions of the object as studied above were made in each case from the object in its initial position. Revolutions may also be made in sequence, i. e., by starting the second revolution from the first and the third from the second. The same principles and methods apply as before. See Plate VII.

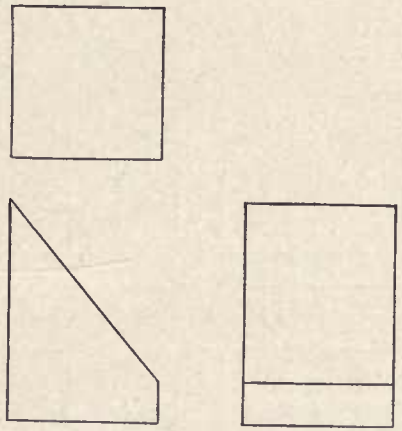


FIG. 29.—Projections of an Object having One Face not Parallel to a Plane of Projection.

In applying the principles of projection in drawing it must be fully understood that every line of the drawing is *the projection of a surface.*

Projectors, i. e., construction lines in projection, should be drawn solid and very light.

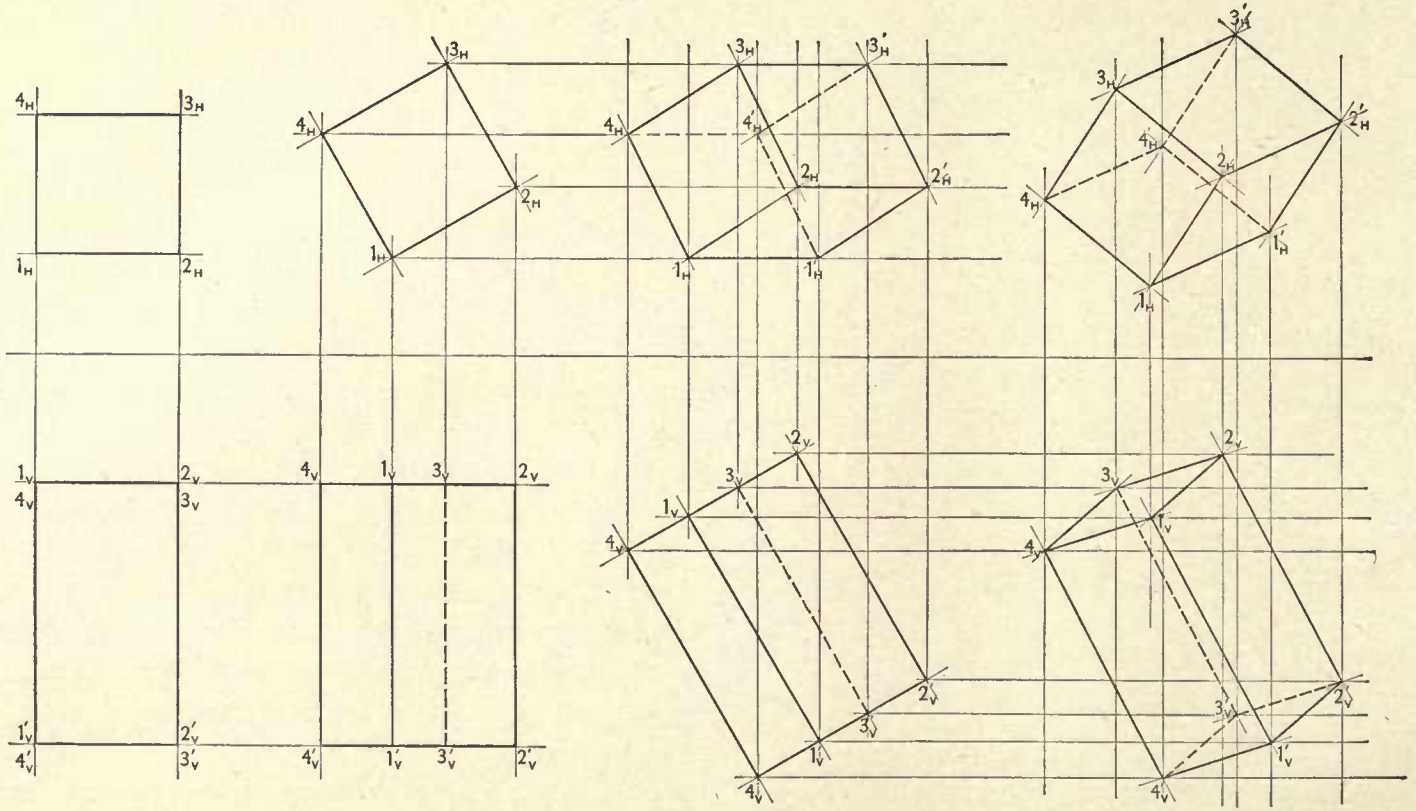
61. It has been shown that the face of an object is projected in its true shape and size only when it is parallel to the plane of projection. If the face to be represented is not parallel to a plane then it must be made parallel when it is desired to have a projection in its true shape and size. This is accomplished in either of two ways; (*a*) by revolving the object or its face into a position parallel with the plane, as explained above, or, (*b*) by making the plane itself parallel to the face. For this purpose one of the three regular planes (V, H or P) may be used, or an additional plane may be used. Such a plane is called **an auxiliary plane.**

62. **An auxiliary view** is a projection upon an auxiliary plane. In Fig. 29 is represented an object one of whose faces is not parallel to a plane; this face is therefore not projected in its true shape and size.

The method of obtaining the desired projection by the use of the auxiliary plane is shown in Fig. 30. The figure ABCD thus found is a projection of the top face of the object in its true shape and size. It will be seen that the auxiliary traces are drawn respectively parallel and perpendicular to the face to be projected, the principles of projection previously explained are then applied to determine the view.

63. An auxiliary plane may be used in any manner desired, but it should be set up perpendicular to one of the regular planes of projection and revolved about one of its traces into the plane of the paper.

In practical work it is customary to draw only the face required rather than the whole view and to work the prob-



(*a*) Object parallel to all planes.

(*b*) Object in (*a*) revolved about an axis perpendicular to H. Top view unchanged.

(*c*) Object in (*b*) revolved about an axis perpendicular to V. Front view unchanged.

(*d*) Object in (*c*) revolved about an axis perpendicular to H. Top view unchanged.

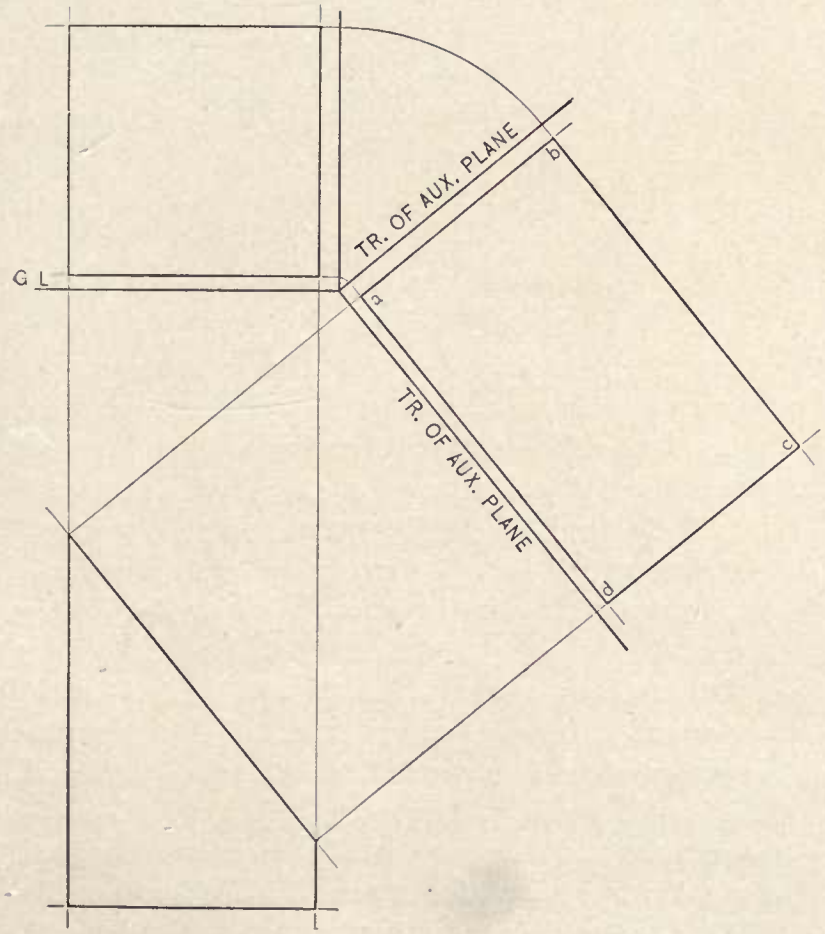


FIG. 30.—Projection of a Face upon an Auxiliary Plane—called *Auxiliary View*.

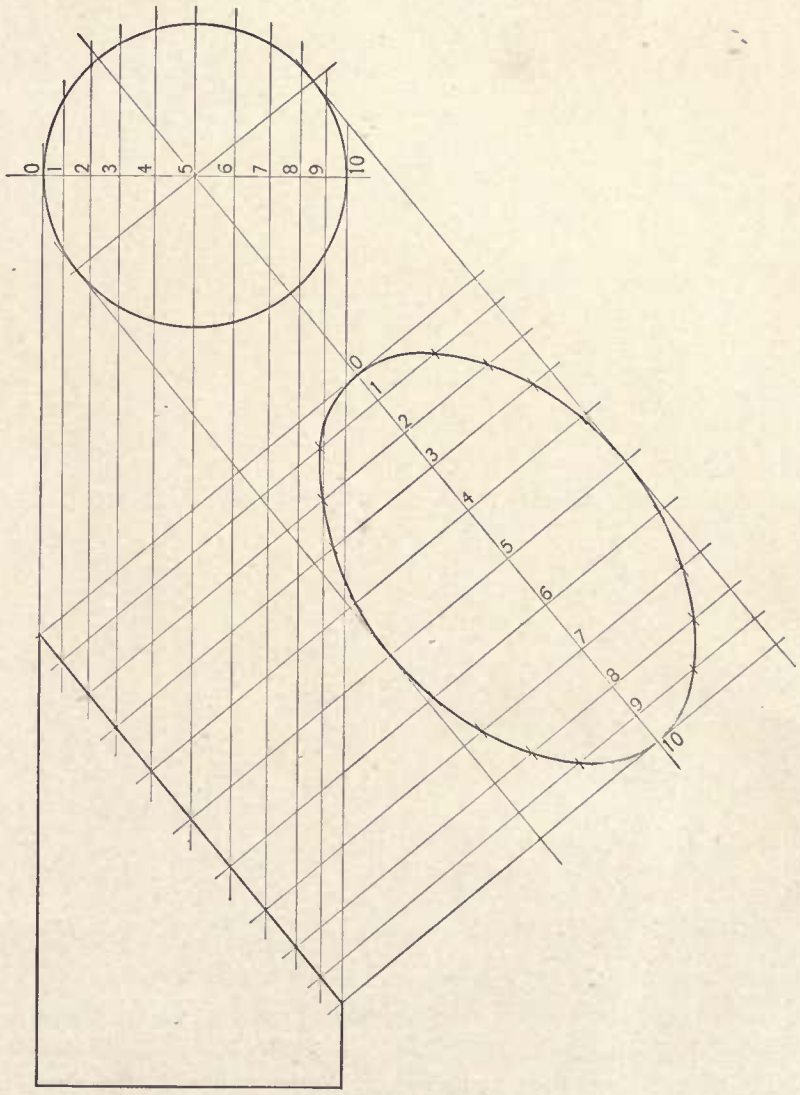


FIG. 31.—Showing Method of Constructing an Auxiliary View, omitting Traces.

lem from center lines, omitting the traces. This method is illustrated in Fig. 31, the ellipse being determined by points laid off from the true measurements found in the other views as shown.

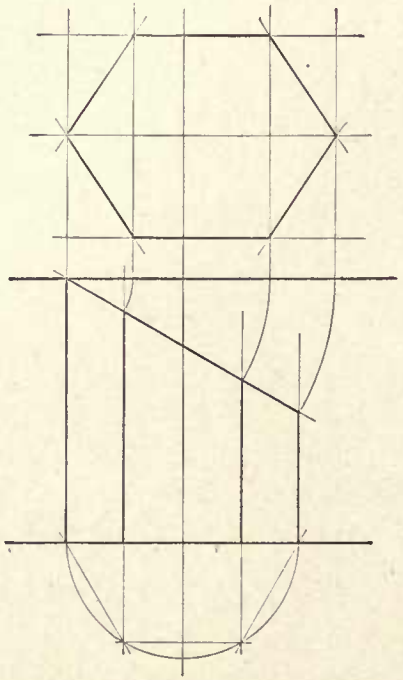


FIG. 32.—Auxiliary View obtained by Revolving the Face Parallel to a Plane.

64. A further application of the principle of the auxiliary view is exemplified in Fig. 32. The outline of the base of the object shown is found by revolving one-half of it about a center line. In symmetrical figures it is necessary to construct only one-half of the view.

In a similar manner the true size and shape of the top face is determined by revolving the plane of that face into a position parallel to a plane of projection, which in this case is H.

By the method of the auxiliary view it is possible to determine projections of geometrical figures and irregular curves and shapes; a sufficient number of points being found they are joined and the projection is obtained.

65. The true length of a line is frequently required in the solution of problems. It was stated above that an object placed oblique to a plane of projection will be represented by foreshortened faces on that plane; therefore any edge of the object will be represented also by a foreshortened line. It was stated also that a line will project on a plane in its true length when it is parallel to that plane; *the true length of a line may be found, therefore, by making the line parallel to the plane.* This may be accomplished by the following method:

A line, AB, is represented in Fig. 33 by its H and V projections. To make the line parallel to V its H projection is revolved about A_h as a center until it is parallel with GL, $(A_hB'_h)$. If the line AB were actually revolved in this manner the point B would describe in space a horizontal circle, the projection of which on H is $B_hB'_h$ and on V is $B_vB'_v$. As the H and V projections of a point lie in the

same vertical line, B'_v must be the V projection of the point B after the line has been made parallel to V. The true length of the line is therefore $A_tB'_v$.

The revolution could have been made parallel to H

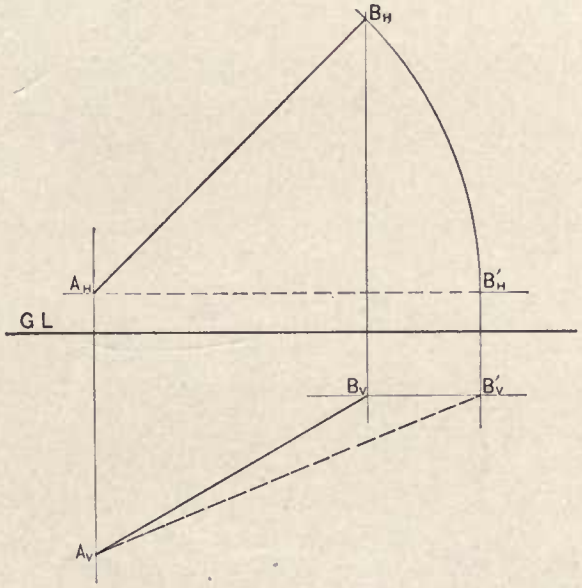


Fig. 33.—Showing Method of Finding the True Length of a Line.

instead of V and the true length of the line would then have been its H projection.

66. The angle which $A_tB'_v$ (Fig. 33) makes with GL is the true size of the angle which AB makes with H.

It should also be noted that a projection of a line parallel to GL indicates that the line itself is parallel to a plane.

67. The arrangement of views shown in Fig. 25 is determined by the manner in which the planes of projection are swung into the plane of the drawing as explained in

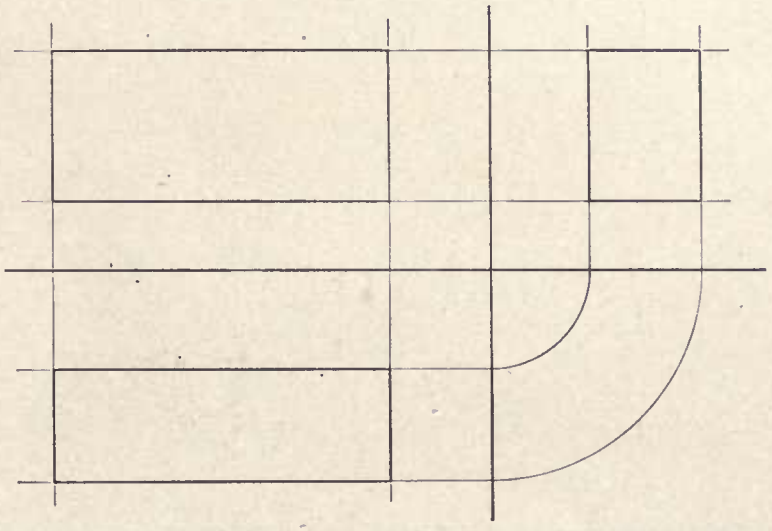


Fig. 34.—Showing Arrangement of Views when V and P are swung into same Plane with H.

paragraph 53. If the V and P planes are swung about their traces into the H plane the arrangement of views would appear as shown in Fig. 34. This method is preferred by some and is geometrically correct, but it is not used as extensively in practice as the other.

CHAPTER IV

GEOMETRY OF DRAWING

(*A*) The Intersection of Surfaces

68. In the construction of certain kinds of objects, **full-sized patterns** of the outside surfaces are required. The pattern is spread out flat on the material to be used and the latter is cut so that when rolled, folded, or formed it will make the object. Applications of this subject may be found

FIG. 35.—Application of Intersections and Developments in Sheet-Metal Construction.

in practical arts as, for example, in tin-smithing—pans, funnels, boxes, cans and many other articles; in sheet-metal construction (see Fig. 35)—ventilators, sky-lights, cornices and various kinds of formed work; and in patterns for boiler-making.

69. Many of the objects requiring patterns are constructed of two or more parts which are usually geometrical forms that intersect. The objects shown in Fig. 36 are built of two intersecting cylinders, each of which was cut from a pattern or development of its surface. In order to lay out the pattern or development it is necessary to determine the curve formed by the intersection of the two

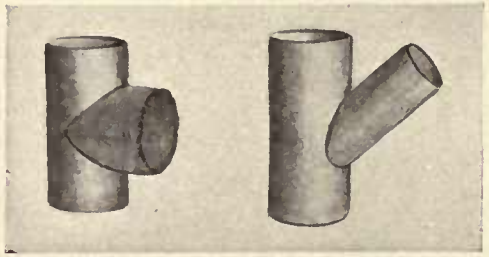


FIG. 36.—Geometrical Forms Intersecting.

surfaces. Geometrical solids of the type forms are used as the basis for the study of the principles of this subject because nearly all practical problems are fundamentally geometrical in character.

70. A line of intersection is a line common to any two surfaces that meet. The intersection of two plane surfaces

is a straight line (see Fig. 37); of a plane and curved surface, a straight line or a curve (see Fig. 38); of two curved surfaces, a curve (see Fig. 39). The character of the intersection is determined by the position of the planes and surfaces with reference to each other; thus, in Fig. 38, it is seen that the intersection of a plane and cylinder may be a straight line or a curve.

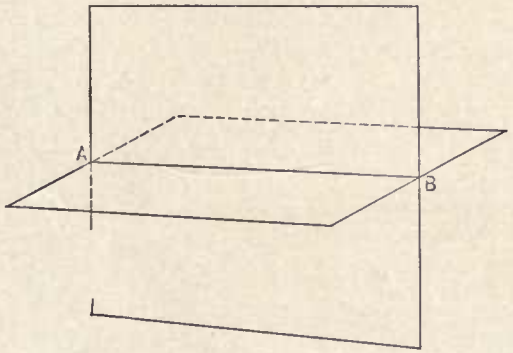
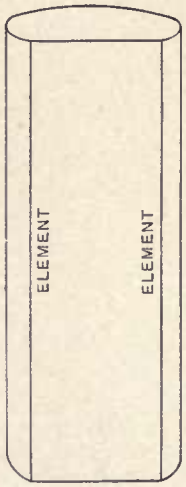
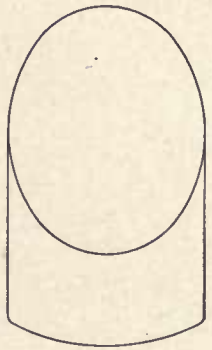


Fig. 37.—Intersection of Two Planes.



(a)
(*a*) Straight Line.



(b)
(*b*) Curve.

Fig. 38.—Intersection of a Plane with a Curved Surface.

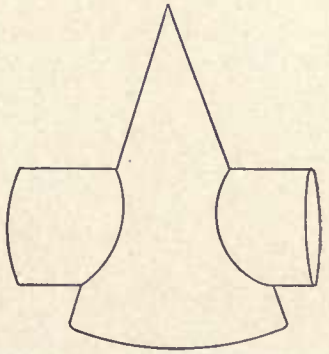


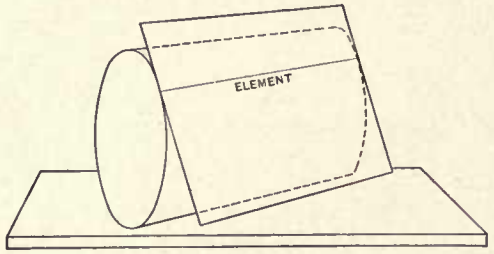
Fig. 39.—Intersection of Two Curved Surfaces.

71. The line of contact formed by a plane tangent to the surface of a cylinder or cone is known as an **element** (see Fig. 40). The intersections of any plane parallel to a tangent plane and cutting the cylinder are also elements (see Fig. 38).

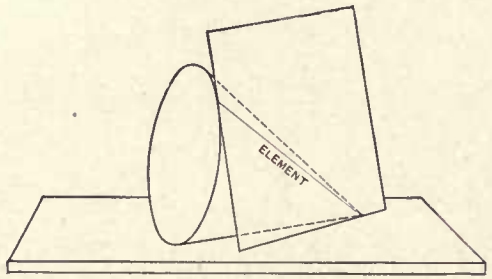
72. Intersections are determined by *two general methods;* the simpler one will be demonstrated first. Every point on the curve is the intersection of two elements; therefore the problem is to find the elements which correspond and determine by projection their points of intersection. Through a number of points thus determined the curve may be drawn.

73. Two intersecting cylinders are shown in Fig. 41; the curve of intersection is determined as follows: (*a*)

Divide the arc, top view of cylinder B, into any convenient number of parts. Each of these points is the H projection of an element in B, as *a b*. (*b*) Find the V and P projections of the same points; they are the projected elements



(*a*) Cylinder.



(*b*) Cone.

FIG. 40.—Tangent Plane producing an Element.

in B corresponding to their H projections. These elements pierce the cylinder A, intersecting elements of the latter which are determined by the intersections in P of the projected elements from B with the arc *e f*. (*c*) Draw the elements in A; their intersections with corresponding elements in B are points common to both cylinders and therefore determine the curve *c d*.

74. The intersection shown in Fig. 41 is symmetrical, therefore the whole of it need not be drawn. As the axes of the cylinders A and B intersect, the curve of intersection on the back coincides with that on the front; otherwise there would be a difference. The limiting point, *c*, of the intersection is found by projecting the point where the extreme element of B in the side view pierces the cylinder A.

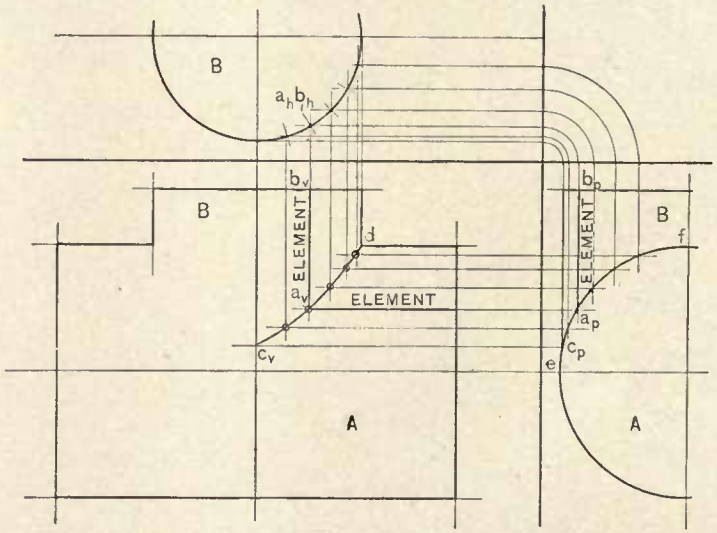


FIG. 41.—Cylinders Intersecting.

75. The method of the auxiliary plane for the determining of intersections is, in general, to draw a number of

planes so chosen that they shall cut either straight lines or circles from the surfaces. The points in which these lines intersect are points on the curve, as the lines lie in the same plane and also in the surfaces cut by the plane.

76. In Fig. 42 are shown two cylinders intersecting ob-

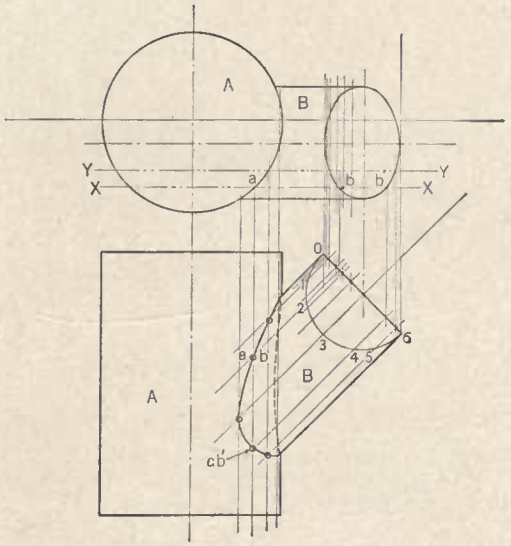


FIG. 42.—Cylinders Intersecting Obliquely.

liquely. The line xx is the trace of an auxiliary plane parallel to V. This plane cuts an element, a, from the cylinder A and two elements b and b' from B. The projections of these elements intersect at ab and ab' which are points on the curve of intersection. In like manner other points are determined by the plane YY and so on, as many such auxiliary parallel planes being used as may be required to give sufficient points to determine the intersection.

In a similar manner the intersection on the back is determined. It is not the same as the front in this case

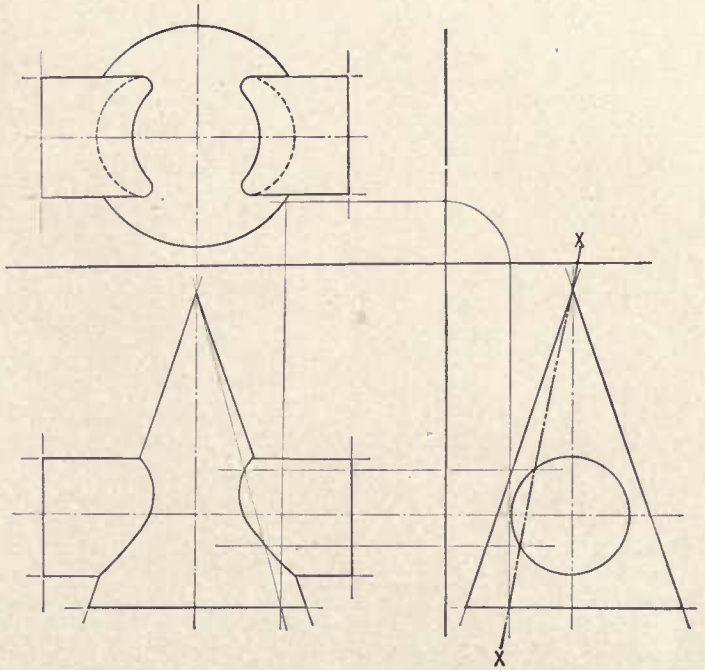


FIG. 43.—Cylinder and Cone Intersecting.

because the axes of the cylinders do not intersect. At least two of the required points are usually found by each plane. The planes should be drawn so that the lines cut are either straight or circles.

77. In general, either of the two methods given may be used to determine intersections, but in certain problems one method may be preferred or the other not adapted.

In determining the intersections of prisms and pyramids,

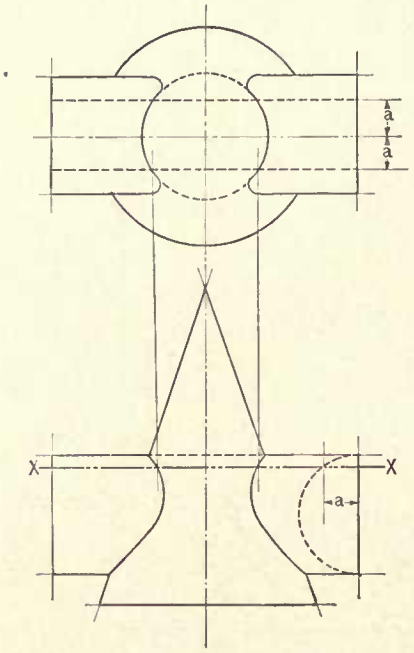


FIG. 44.—Cylinder and Cone Intersecting.

the auxiliary plane cannot be used to advantage, as the intersections, instead of being curves, are composed of short, straight lines. Such intersections may be determined by the use of elements and the method is the same as that previously explained.

78. In finding the intersections of a cylinder and cone, auxiliary planes may be passed through the axis of the cone, as shown in Fig. 43, or perpendicular to it, as shown in Fig. 44. In both cases the planes are parallel to the elements of the cylinder. In the first case elements are cut

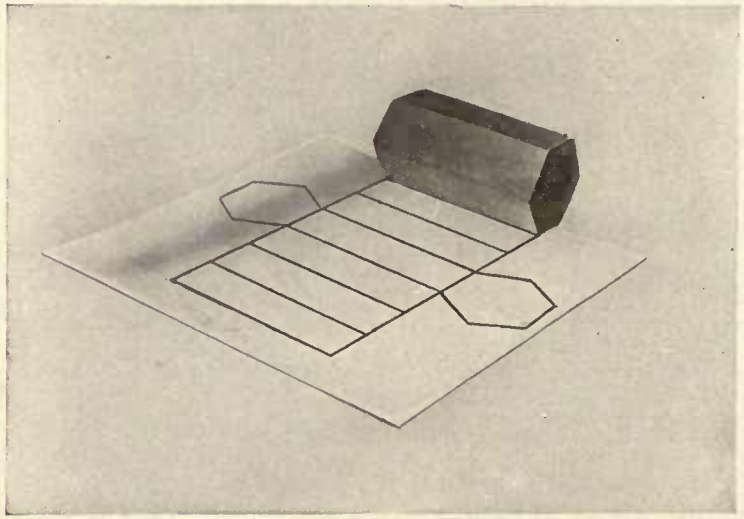


FIG. 45.—A Prism and its Development.

from the cone and cylinder, while in the second, circles are cut from the cone and elements from the cylinder.

(*B*) The Development of Surfaces

79. The development of a surface is the process of laying out a pattern of it on a plane. In paragraphs 68 and 69, the character and general applications of the process were

explained; the methods and principles of construction are demonstrated in the following paragraphs.

80. In Fig. 45 a prism and a pattern of its surfaces are shown. This pattern or **development** was produced by laying each face of the prism on the paper and drawing around it with a pencil. It is obvious that if this development were cut out and folded it would make a prism the same size as the original, because each face of the development is the same shape and size as the corresponding face on the prism. This is the basic principle of this subject and may be expressed thus:

To develop a surface it must be projected in its true shape and size.

It is evident, therefore, that a developed surface must always be drawn to **scale full size.**

81. From the preceding, it is apparent that *the chief factor in determining the development of a surface is the finding of the true lengths of the lines bounding it.* This is done according to the principles and methods of projection and intersections previously explained.

82. The problems of this subject may readily be grouped according to types as follows:

(*a*) The prism and cylinder.

(*b*) The pyramid and cone.

(*c*) Intersecting solids.

(*d*) The oblique cone.

Each type will be demonstrated in the order given.

For the purposes of practical construction, it is necessary to allow extra material for laps and seams in making a development. However, this allowance is omitted in this treatment because its application is a matter of shop knowl-

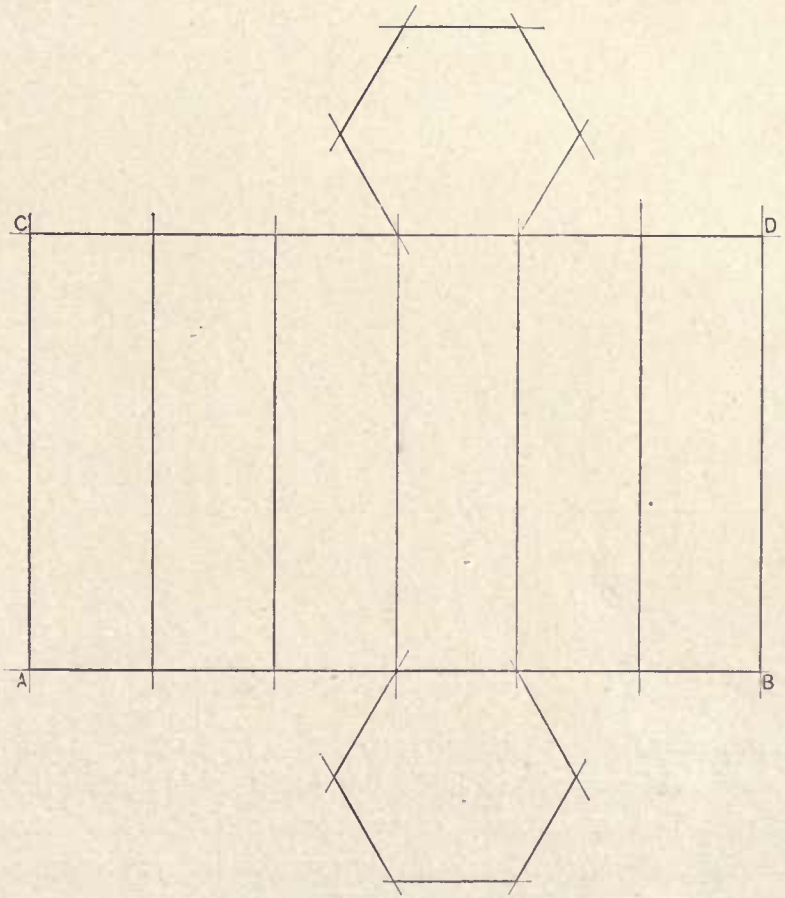


FIG. 46.—Development of a Prism.

edge and experience which can be understood only in the practice of the trades.

83. Development of the right prism and cylinder. To develop a prism similar to that shown in Fig. 45, a base line AB, or "stretchout," is first drawn (see Fig. 46). This

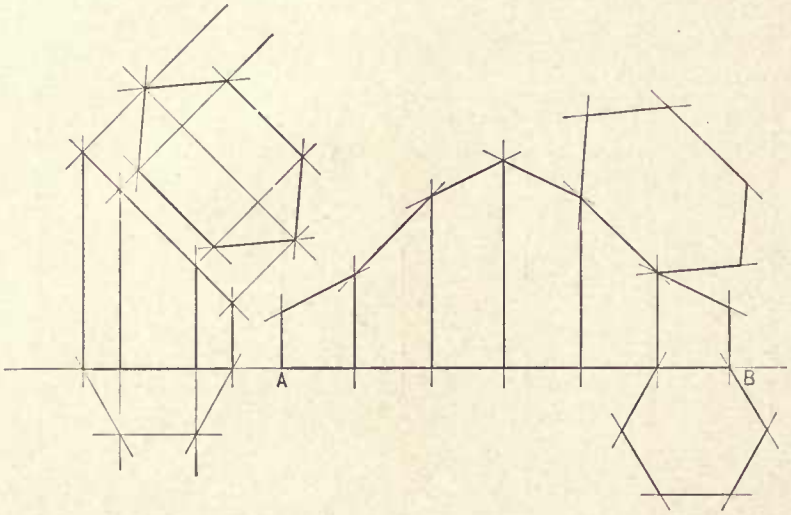


FIG. 47.—Development of the Frustum of a Prism.

is divided into as many parts as the prism has sides, each division corresponding in length to the width of a face. Perpendiculars are next drawn from each point on the stretchout. The altitude of the prism is laid off and the upper base line, CD, is drawn. The upper and lower bases are then constructed geometrically, exact size, and the development is complete.

84. The method explained in the preceding paragraph is sufficiently general to cover prisms with irregular bases as well as regular, and prisms with any number of sides.

As the cylinder is a prism having an infinite number of sides, its development is similar to that of the prism; the

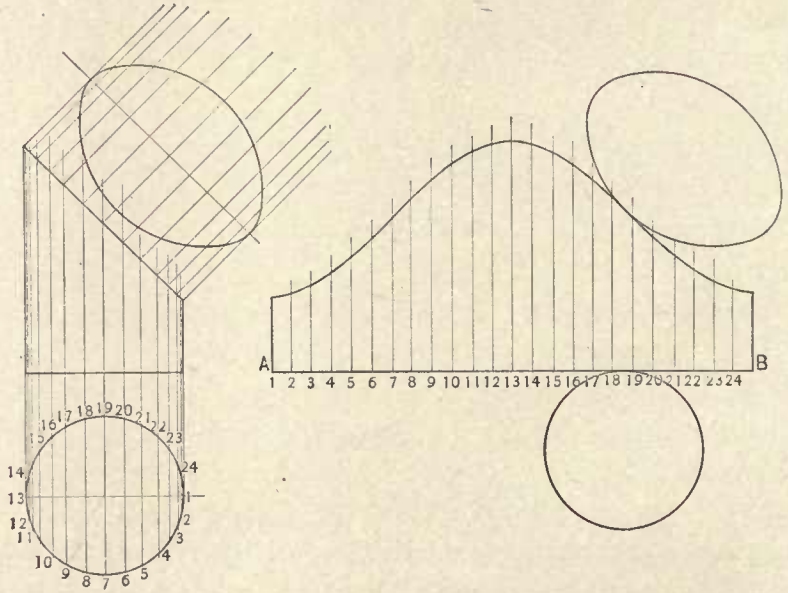


FIG. 48.—Development of the Frustum of a Cylinder.

stretchout being laid off equal to the rectified circumference of its base.

85. If the top part of the prism is cut off, the lower part is called a **frustum.** A frustum is developed in the same manner as the whole prism except that, instead of drawing

the upper base line, CD, the length of each perpendicular must be laid off separately according to the lengths of the corresponding edges, and the points thus found joined by straight lines. The development of the frustum of a prism is shown in Fig. 47. The true lengths of the various edges are obtained by projection as shown.

86. The development of the **frustum of a cylinder** is shown in Fig. 48. The circumference of the base is divided into any convenient number of equal parts which are projected as elements. The stretchout, AB, is divided into the same number of equal parts; perpendiculars are drawn and numbered to correspond with the elements, the lengths of which are then laid off. Through the points thus found a curve is drawn, which is the boundary of the upper base.

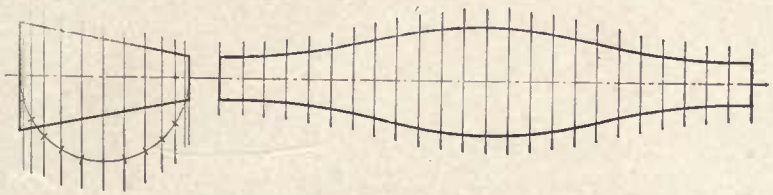


FIG. 49.—Development of the Double Frustum of a Cylinder.

In practice it is customary to make the seam on the shortest element.

87. If a cylinder has neither of its bases perpendicular to its axis, it may be developed by taking the stretchout at some midpoint and developing on both sides as shown in Fig. 49. An elbow made up of more than two pieces would have its middle section or sections developed in this manner; the end sections would be developed as in Fig. 48. A four-piece elbow is shown in Fig. 50.

88. **Development of the right pyramid and cone.** The development of the pyramid is very similar in method to that of the prism. A pyramid is shown in Fig. 51.

FIG. 50.—A Four-Piece Elbow.

The first step in the development is to find the true length of a slant edge, *ab*. This is done by the method of finding the true length of a line, section 65, or by drawing the pyramid as shown at (*b*) Fig. 51, so that its slant edge is parallel to V and therefore projects in its true length, *cd*. With this distance as a radius describe an arc (Fig. 52) and lay off on it the points 1, 2, 3, 4,—the true lengths of the

base lines. Join these points with O and draw the base lines as shown to complete the development.

89. To develop the **frustum of a pyramid** proceed in the same manner as explained above. The true lengths of the slant edges must be found and also the true lengths of the portions cut off in each case. These are laid off and the development completed as shown in Fig. 53. The bases may be determined and drawn as before explained. See Fig. 47.

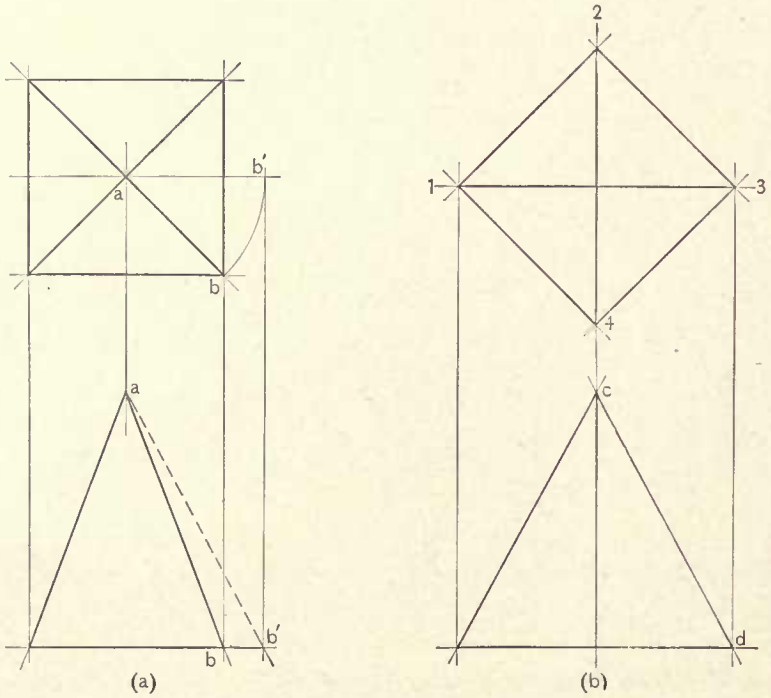


FIG. 51.—A Pyramid.

90. The development of a **cone,** or its frustum, is the same in general method as the pyramid. The cone may be considered as a pyramid of an infinite number of sides—

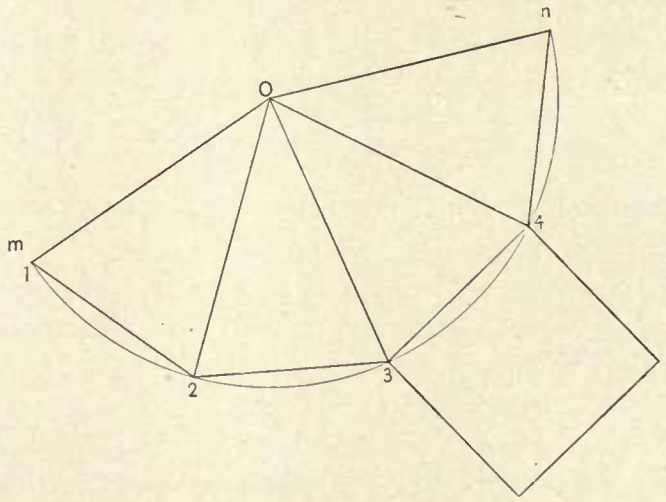


FIG. 52.—Development of a Pyramid.

the elements of the cone corresponding to the edges of the pyramid.

91. To develop the cone, divide the circumference of the base into a convenient number of equal parts as in Fig. 54. Then, with a radius equal to the slant height (true length of an element), draw an indefinite arc and lay off the circumference of the base on this arc. The usual

method of doing the latter is to step off with the dividers the divisions from the circumference of the circle. While this is not strictly accurate, the error is slight and it is the method generally followed in practice, a slight allowance being made for the deficiency.

92. The **frustum of a cone** is developed in the same manner as the pyramid and as explained in the preceding paragraph. The elements are revolved to determine their

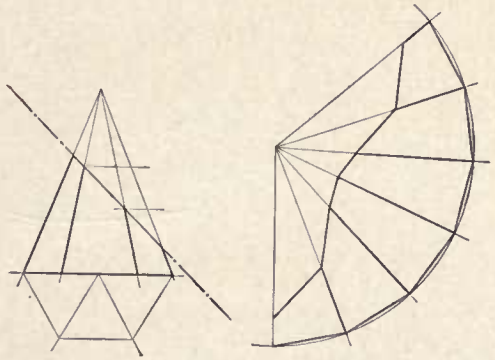


FIG. 53.—Development of the Frustum of a Pyramid.

true lengths, which are then laid off, and through the points thus found a curve is drawn.

93. The Development of Intersecting Solids. To develop the surfaces of solids which intersect, it is necessary first to determine their lines of intersection in order to find the true lengths of their elements or edges. This was fully explained in the first part of this chapter. For purposes of study we may classify these problems as follows:

(*a*) Cylinders with axes intersecting at right angles.
(*b*) Oblique cylinders.
(*c*) Cylinder and cone.
(*d*) Prisms.

These will be discussed in order.

94. (*a*) **Cylinders with axes intersecting at right angles** are developed by first determining their intersections, see

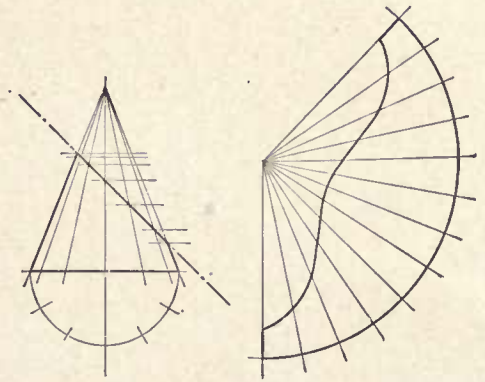


FIG. 54.—Development of a Cone and its Frustum.

Fig. 41. The smaller cylinder is developed as shown in Fig. 55. The stretchout, AB, is drawn equal to the circumference and divided into the same number of parts. Starting with the shortest element, the lengths are laid off as determined by the curve of intersection in the front view. Through the points thus obtained the curve is drawn.

The larger cylinder is developed in a similar manner, the elements being laid off on either side of the center line. It

should be noted that only the elements which determine the curve need to be drawn. See Fig. 56.

95. (*b*) **Cylinders whose axes do not intersect,** or are oblique to each other, or both (see Fig. 42), are treated in the same manner as described in section 94, the only difference in the result being that, in the present case, the curves do not have the symmetry of those above. See Figs. 57 and 58. In dividing the stretchout, care must be taken to have the points spaced in accordance with the location of the respective elements; the distances are not necessarily equal. In Fig. 42 the required distances are 0–1, 1–2, etc., found on the semicircle which is one-half of

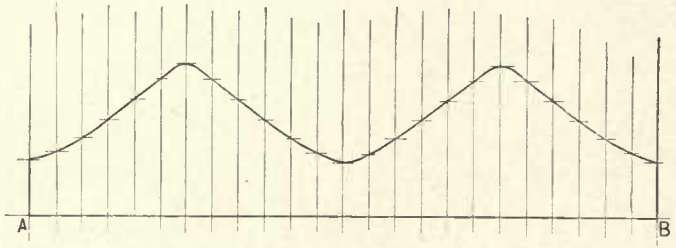


FIG. 55.—Development of Smaller Cylinder of Fig. 41.

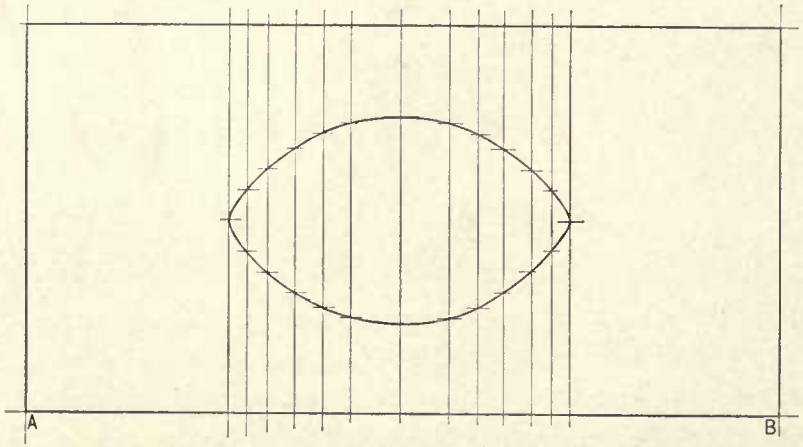


FIG. 56.—Development of the Larger Cylinder of Fig. 41.

FIG. 57.—Development of Smaller Cylinder of Fig. 42.

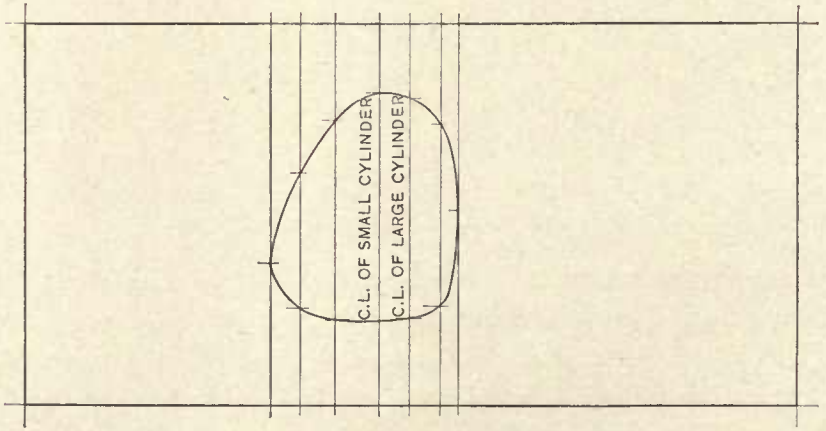


FIG. 58.—Development of Larger Cylinder of Fig. 42.

the revolved base of the cylinder B. By giving the matter a little thought the pupil can readily understand this.

96. (*c*) The development of **intersecting solids, like the cylinder and cone,** Fig. 39, are obtained by first determining the intersections as previously explained; either the method of elements or of auxiliary planes may be used. The stretch-outs are drawn and spaced and the elements laid off in the same manner as given above for similar developments. The development of the cylinder shown in Fig. 39 would be

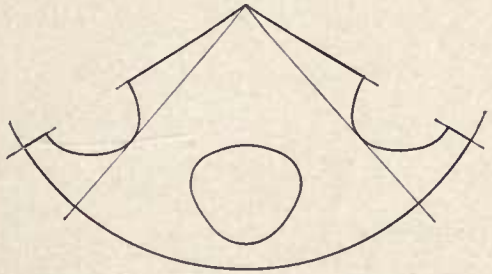


FIG. 59.—Development of the Cone of Fig. 39.

made in two parts, and each would appear similar to that shown in Fig. 55. The development of the cone is shown in Fig. 59.

97. (*d*) In cases where **the development includes either prisms or pyramids,** or both, the method of procedure is no different from that already explained. The edges of the prism or pyramid are treated as elements. The intersections of plane surfaces will give straight lines which will therefore develop into a broken boundary instead of a curve. See Figs. 47 and 53.

98. Triangulation is an approximate method of development which is commonly used in practical work. It is particularly adapted to applications of the **oblique cone,**

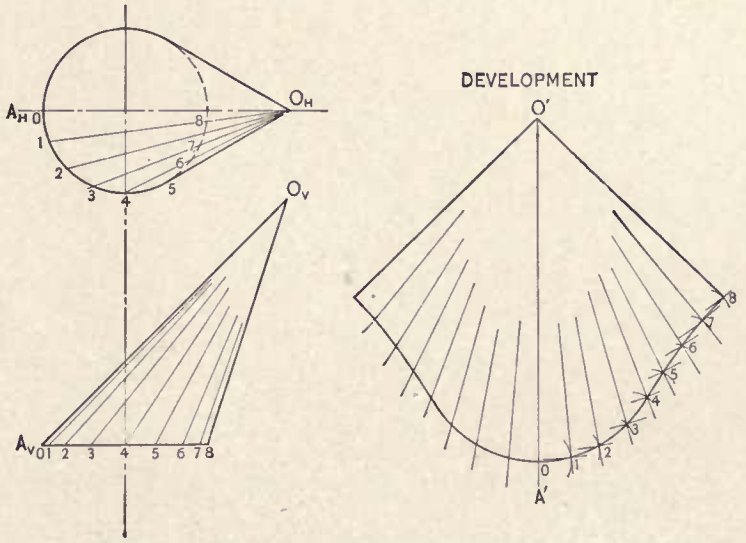


FIG. 60.—Development of Oblique Cone by Tri ngulation.

which can be more readily and accurately developed by this method. The surface to be developed is divided into triangles having short bases. The true lengths are then found of each of the sides of the triangles. The development consists of constructing these triangles with their common sides joining. See Fig. 60.

99. The sides of the triangles are elements of the cone and their true lengths are determined in the usual manner. The bases of the triangles are short chords found in the top view of the base of the cone which is divided into small parts.

To construct the development draw a centerline, O′A′, and lay off on it the distance, O_6A_6. Then, with O′ as a center, draw arcs with radii equal to the true lengths of the sides. Next draw arcs with a radius equal to the base; their intersections with the arcs previously drawn give points which determine the curve.

CHAPTER V

WORKING DRAWINGS

100. A working drawing is one showing the form, size and construction of an object.

Its purpose is to convey to the mechanic sufficient information to enable him to make the required object. To this end the working drawing must be clear, accurate, and complete. Nothing should be omitted that is essential or that would make the drawing obscure or doubtful; on the other hand unnecessary views and lines should be left out.

101. The basis of the working drawing is orthographic projection as explained in Chapter III.

It does not follow, however, that the views of a working drawing must be in all respects true or complete projections. For the sake of clearness it is frequently advisable to depart from the exact rules of projection.

The necessary views, together with the dimensions and other essential information, constitute the working drawing. A working drawing of a box is shown in Fig. 61.

102. In making working drawings, good execution depends upon: (*a*) The proper selection and representation of views and details. (*b*) Conformity to standard practice. (*c*) The selection of essential and most suitable dimensions. (*d*) Complete explanatory notes.

103. In order that working drawings may be made and read with ease and facility, certain symbols have been

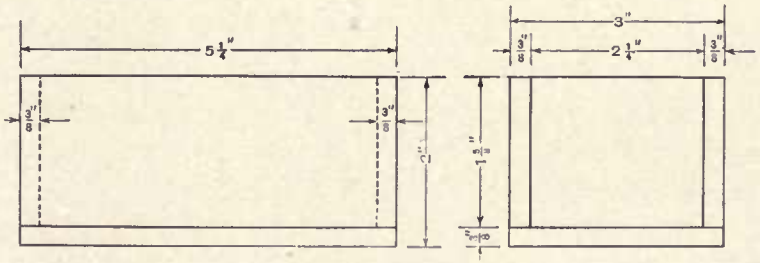


FIG. 61.—Working Drawing of a Box.

adopted which are known as **conventions.** These have come to be recognized as more or less "standard." Their forms and uses are explained in the following paragraphs.

104. Kinds of Working Drawings. A drawing that is made roughly, without particular reference to the actual

dimensions, is a **sketch.** If the dimensions are indicated, it is then called a **working sketch.**

A drawing which shows the various parts of an object assembled in their relative positions is known as an **assembly drawing.** Such a drawing usually has only a few of the larger reference dimensions upon it, or none at all.

A **detail** is a drawing of a single part to a larger scale than the assembly. It is intended for construction purposes and should therefore be dimensioned.

A scale drawing is one that is made exactly in accordance with actual dimensions. If it is drawn to the same size as the object, it is said to be "scale full size" or 12″=1 ft. A drawing may be one-half size, or to the scale 6″=1 ft. and so on.

Drawings should be made to as large a scale as possible. In no case should other than a standard scale be used. Details should be drawn full size when practicable.

105. An object that is too large to be drawn actual or full size is drawn to a **reduced scale.** For example, suppose that an object is of such a size that the drawing of it must be made one-twelfth as large. It is evident that a distance of one foot on the object would be represented by a distance of one *inch* on the drawing, or, in other words, the foot on the drawing is one-twelfth of the corresponding "standard" foot on the object. The standard foot is divided into twelve inches, therefore by dividing the reduced foot into twelve parts each part will represent one inch.

A scale graduated in the manner described above is shown in Fig. 62, and a measurement of 4 ft. 3 in. is indicated. It will be seen that a drawing may thus be made to a reduced scale without the necessity of computing fractional measurements, which would be a laborious method and liable to error.

It should be noted that the inch on the reduced scale is divided into fractional parts similar to the full-sized scale.

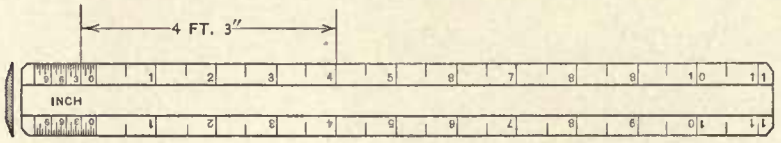


FIG. 62.—A Scale.

106. The following are the **common standard scales:**

Scale 12″=1 ft., full size.
Scale 6″=1 ft., half size.
Scale 4″=1 ft., third size.
Scale 3″=1 ft., quarter size.
Scale 2″=1 ft., sixth size.
Scale $1\frac{1}{2}$″=1 ft., eighth size.
Scale 1″=1 ft., twelfth size.
Scale $\frac{3}{4}$″=1 ft., sixteenth size.
Scale $\frac{1}{2}$″=1 ft., twenty-fourth size.
Scale $\frac{3}{8}$″=1 ft., thirty-second size.
Scale $\frac{1}{4}$″=1 ft., forty-eighth size.
Scale $\frac{3}{16}$″=1 ft., sixty-fourth size.
Scale $\frac{1}{8}$″=1 ft., ninety-sixth size.

The scales that are used most frequently are the 12″, 6″, 3″, 1½″ and 1″ for ordinary drawings and ¼″ and ⅛″ for plan drawings.

Drawings of very small objects are frequently drawn to an increased scale.

107. Views. In making a working drawing of an object, the views that show it best should be selected, using sections and details in preference to other views, and omitting

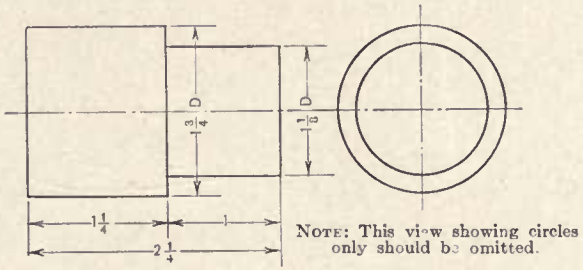


FIG. 63.—Working Drawing of a Cylindrical Piece.

unnecessary views altogether. Where a note will serve instead, a view may be omitted. A view which shows only circles should be omitted and "D" or "Dia" (diameter) should be placed after the circular dimensions. See Fig. 63.

The drawing should show the object in a natural position. When several details are shown on the same sheet, keep the related parts near together.

The arrangement of views should conform to the principles of projection as explained in paragraph 48.

108. Conventional Lines. *Visible edges and outlines* of objects should be represented by **full lines** of medium width. See Plate VIII.

Invisible edges and outlines of objects should be represented by **broken lines** consisting of short dashes, separated by spaces of about one-half the length of dashes.

Center lines and lines indicating the position of the plane in which a sectional view is to be made should be broken lines consisting of **alternate short and long dashes.**

Construction lines including all lines which are in the nature of diagrams and are not essential outlines or edges of the object represented should be **fine dotted lines.**

In a pencil drawing it is customary to draw center and construction lines full and light.

109. *Dimension lines* should be **fine, broken lines,** consisting of long dashes, interrupted for the figures expressing the dimension. These lines should be terminated by *arrowheads* whose points touch the proper extension lines.

Extension lines which project from points between which dimensions are to be expressed should be **fine, broken lines** consisting of dashes of medium length. Such lines should not touch the outline of the object, and should extend slightly beyond the point of the arrowhead on the dimension line.

Fine full lines in red ink may be substituted for broken center, dimension, extension and construction lines, except that in drawings which are traced for printing the broken lines in black ink are to be preferred.

VISIBLE LINE

INVISIBLE LINE

SECTION LINE

DIMENSION LINE

CENTER LINE

REFERENCE LINE

ARROW HEADS

RIGHT WRONG

INDICATE FEET AND INCHES THUS:

4′-0 3/4″

OR THUS:

5 FT. 3″

2 3/4″

1/2″

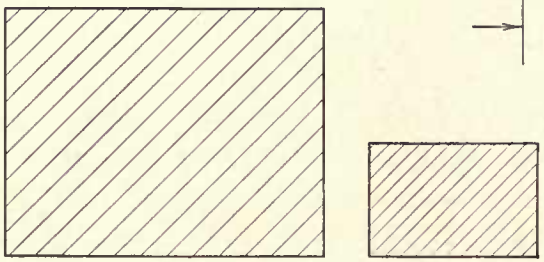
1/4″

ARROW POINTS SHOULD TOUCH EXTENSION LINES. WITNESS MARKS, OR EXTENSION LINES MUST NOT TOUCH THE VIEW, UNLESS DRAWN IN RED INK.

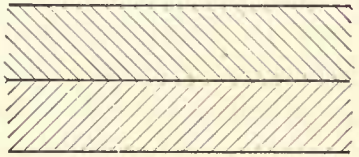
3/8″

2″

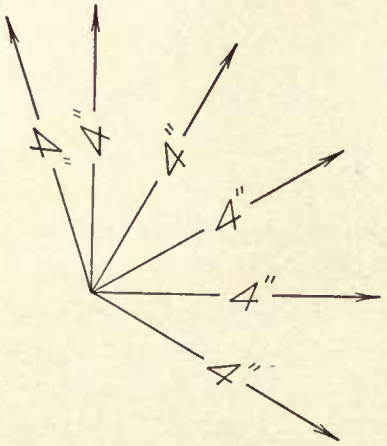
DIMENSION CIRCLES BY THEIR DIAMETERS.



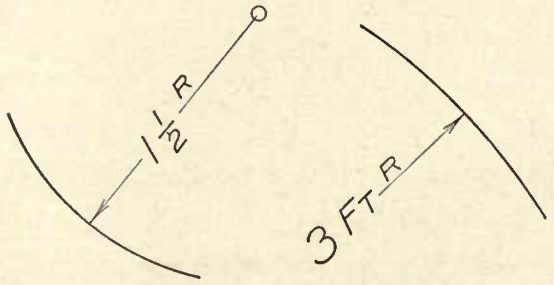
SECTION LINES SHOULD BE SPACED ACCORDING TO THE AREA.

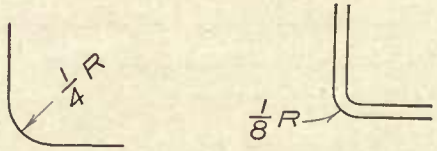


SECTION DIFFERENT PIECES IN DIFFERENT DIRECTIONS.



DIMENSONS ALL READ RIGHT HANDED.





DIMENSION ARCS BY THEIR RADII.

110. Dimensioning. The most important feature in the making of a working drawing is the dimensioning. The selection and placing of dimensions require care, good judgment, and experience. The ultimate test of a working drawing is its interpretation, which means to the mechanic, not only a mental picture of the completed object, but also finding the correct dimension in the right place.

A knowledge of shop processes and methods of production are essential to a complete understanding of how to make shop drawings. The student should endeavor to acquire this training and he should also study examples of good drafting practice in connection with the principles.

111. Dimensions should be placed outside the views as far as practicable, and should be grouped. It is preferable to place the dimensions to the right of the views. Place as many dimensions as possible in connection with one view—the one furnishing the most information—and do not repeat them. See Fig. 64.

Always dimension to visible edges, if possible. Over-all dimensions should always be given, and these should be placed outside of all sub-dimensions.

112. The figures denoting dimensions should read from the bottom and right; they should never be placed on a center line or on a line which would cross them.

Fractions should be written thus—$\frac{3}{4}$; not thus—3/4.

Figures should be placed so that they may be erased without touching a line of the drawing. Lines for dimensions should be at least $\frac{1}{4}''$ apart.

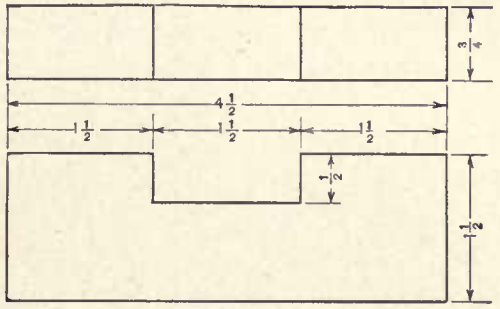


Fig. 64.—Illustrating Principles of Dimensioning.

Do not allow the dimensions to be crowded or to interfere with each other or with the lines of the drawing.

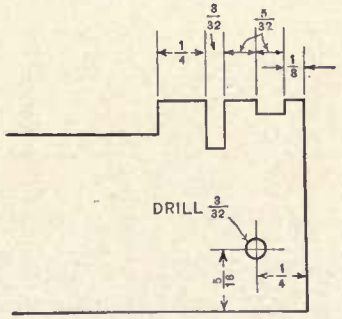


Fig. 65.—Illustrating Close Dimensioning.

If a dimension space is small, place the figures outside and invert the arrows, or indicate by a leader the part to which the figures refer. See Fig. 65.

Circles are dimensioned by their diameters and arcs by their radii. Dimensions should read to the center lines of circles and not to the circumference. See Fig. 66.

113. Related dimensions should be given in one view. For example, the diameter, depth, and location of a hole should all be given on the same view.

Dimensions should be chosen with reference to the measurements which will be made in constructing the object, and should indicate full size, independent of the scale.

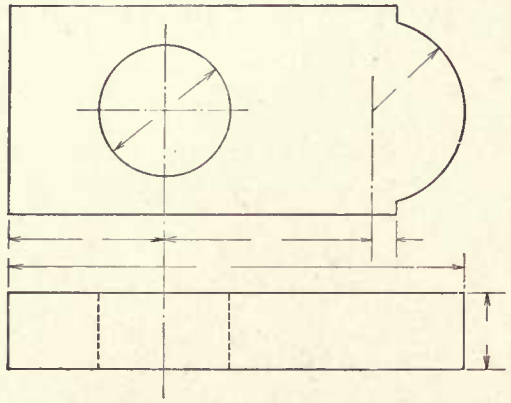


FIG. 66.—Illustrating Principles of Dimensioning.

114. The length, breadth, thickness, and location of every part must be clearly indicated. It is not expected that the workman is to add or subtract dimensions; that is the business of the draftsman.

Sub-dimensions should be added and the total checked with the corresponding over-all dimension.

Denote feet and inches thus:

(*a*) 6′–10″, (*b*) 6 ft. 10″, (*c*) 8 ft. $0\frac{3}{4}$″.

When the greatest dimension does not exceed two feet, figure the whole drawing in inches, omitting the ″ marks. In some cases even greater dimensions are figured entirely in inches.

115. To insure completeness, the dimensioning must be done systematically. *Remember that it is essential to show the length, breadth, thickness, and location of every part.*

Each dimension should be scaled and compared with the computation. Take nothing for granted. A drawing should always be made from the view-point of the one who is to read it.

The notes on a drawing are important. Give all the information needed, and express it accurately and concisely.

Begin the drawing with the most important view, but it is usually advantageous to build up all views simultaneously, projecting from one to another.

116. A section is a view which represents the interior of an object as though it were visible. (See Fig. 67.) The purpose of a section is to show the construction more clearly.

The front view of the object shown in Fig. 67 would be the same if the hole extended all the way through; the side view would be the same if there were a central hole; neither

view, therefore, is suggestive of the real shape of the object. If the object is represented as having been cut open so that the interior is visible or, in other words, if sections are taken on the lines AB and CD, the actual shape of the object is at once apparent.

A section may be defined as a view made by an imaginary plane cutting the object. The part of the object in front of

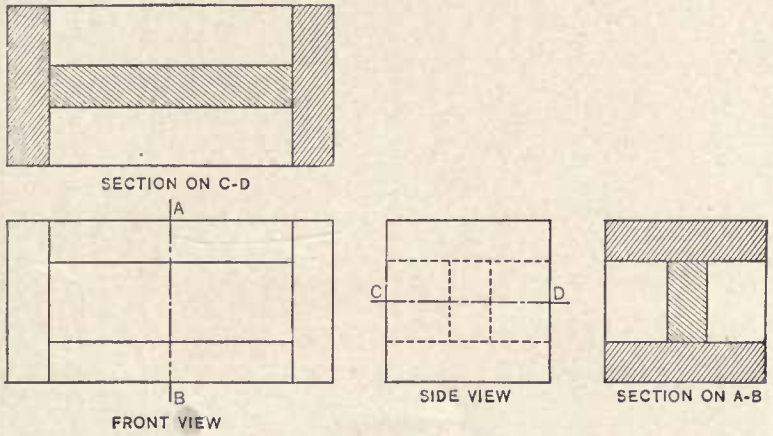


Fig. 67.—Illustrating a Section.

the plane is considered removed and the view of the part remaining back of it is the *sectional view* or *section*.

Sections are usually taken either across or lengthwise of the object and are designated as **cross-section** and **longitudinal section** respectively. Sections are also made horizontally and vertically.

That part of the object which is cut open or made visible by the section is indicated by light, slanting lines, drawn parallel and about $\frac{1}{16}''$ apart. A difference in the direction of slant of section lines denotes different pieces. See Plate VIII.

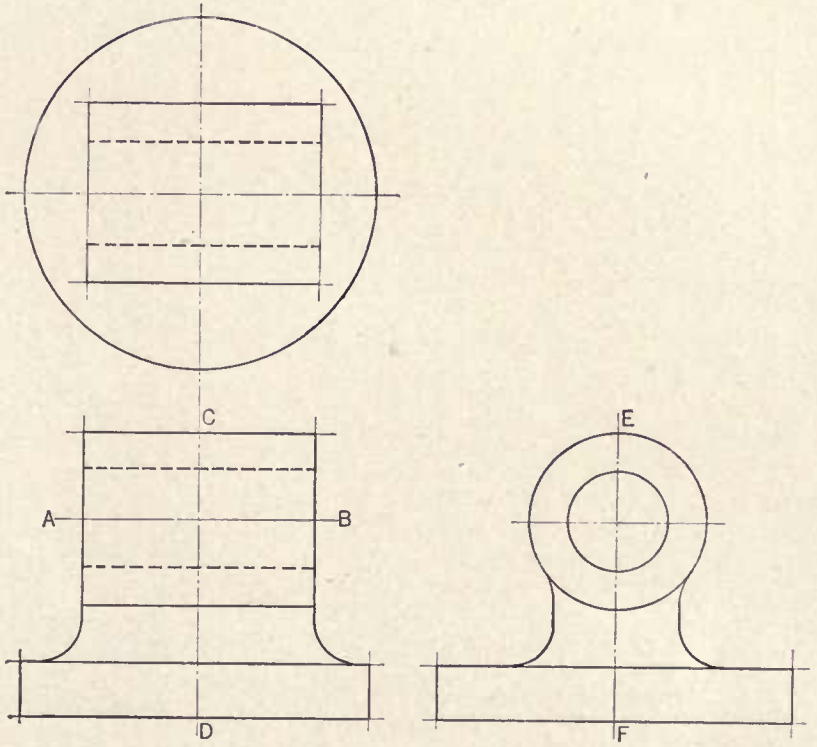
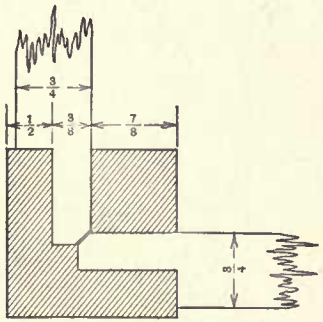
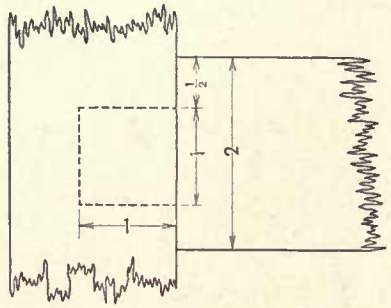
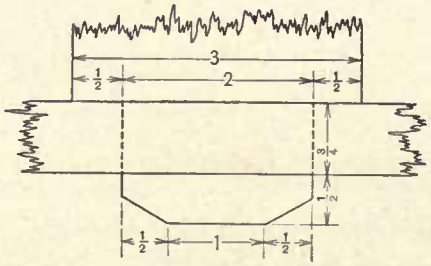


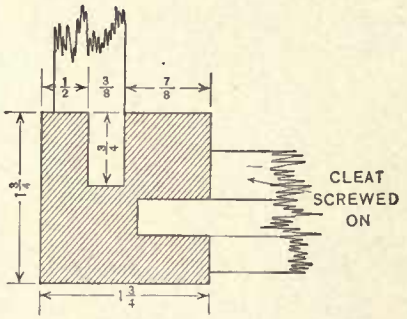
Fig. 68.—Object the Sectional Views of which are shown in Figs. 69–72.

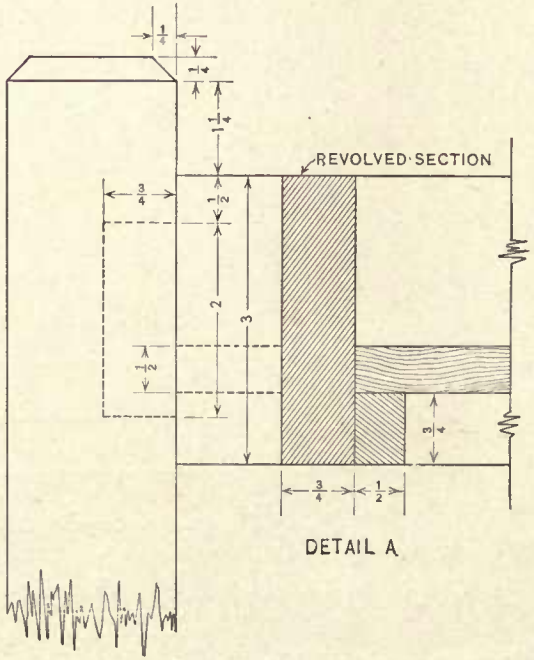
Section lines should be spaced in accordance with the size of the sectional area and should be broken for a dimension within the area. Indicate the place at which a section

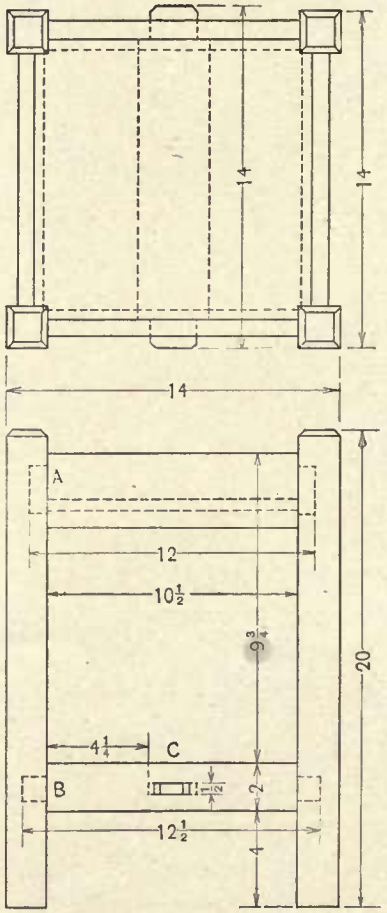



DETAIL B


DETAIL C


CLEAT
SCREWED
ON


REVOLVED SECTION
DETAIL A


14
14
14
A
12
10½
9¾
20
4¼
C
B
2
12½
4

PLANT STAND

is taken. In terms of "projection" this is known as "the trace of the cutting plane," or "section plane."

117. That part of the object which is back of the cutting plane may be omitted from the section view unless it helps to explain it. In some cases parts in the plane of the section may also be omitted. Everything lying in the plane of the section need not be sectioned. This is well shown in the

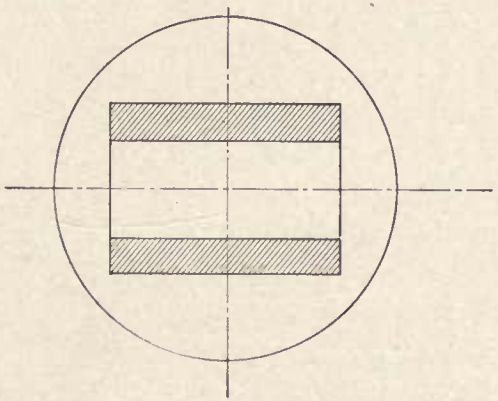


FIG. 69.—Section of Object shown in Fig. 68 taken on Line AB.

top views of details A and B, Plate IX. The contrast between the surfaces which are sectioned and those that are not serves to show the construction more clearly.

118. The **location of a sectional view** usually follows the general arrangement of the other views, i. e., looking at the object from the right, the same location as a right side view, looking from above the same position as a top view, and so on.

119. The **selection of a section** to show the object to the best advantage is of great importance. Consider the object shown in Fig. 68. A section on AB, as shown in Fig. 69, has no features and adds nothing to the representation. The same is also true of a section on CD as shown in Fig. 70;

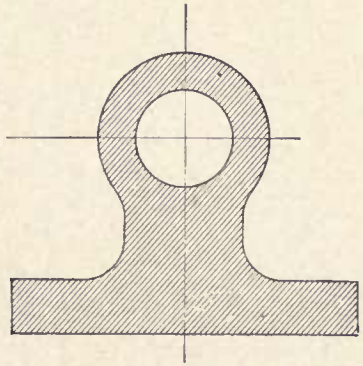


FIG. 70.—Section of Object shown in Fig. 68 taken on Line CD.

the side view is to be preferred. A full section on EF is shown in Fig. 71; this view is a correct projection, but it fails to convey a correct idea of the object and is, in fact, misleading.

A conventional section, as shown in Fig. 72, represents the object clearly and brings out the form.

120. A cross-section may be shown to advantage in some cases by representing it as turned or revolved as

illustrated in Detail A, Plate IX. This method saves time and space.

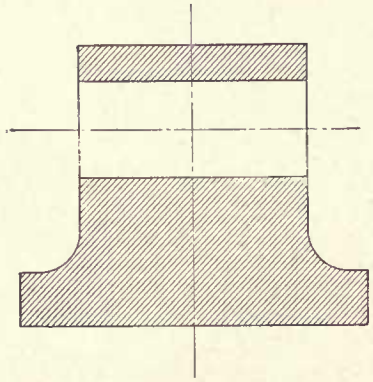


FIG. 71.—Section of Object shown in Fig. 68 taken on Line EF.

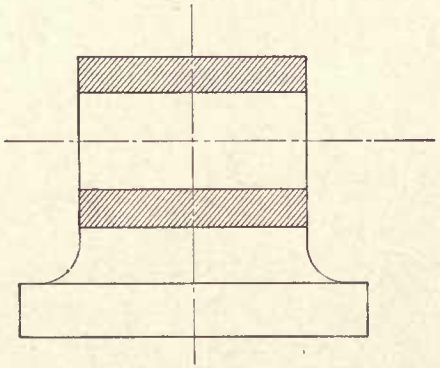


FIG. 72.—Conventional Section of Object shown in Fig. 68.

A piece that is symmetrical may be shown in half section, the other half being drawn as an exterior view. See Fig. 73. In this case it is usual to omit invisible lines.

121. The **kind of material** to be used in the construction of an object is often represented by a characteristic notation.

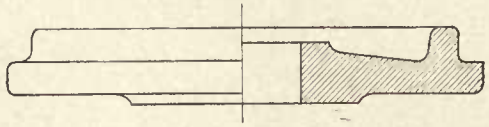


FIG. 73.—Illustrating a Half Section.

This will be illustrated in the following chapters in connection with the various types of drawings.

122. In making a pencil drawing, the section lines should be drawn freehand in patches on the sectioned surface to save time. See Fig. 74. On the inked drawing the lines should be drawn with a ruling pen, fine and light, equally spaced, and covering the entire surface.

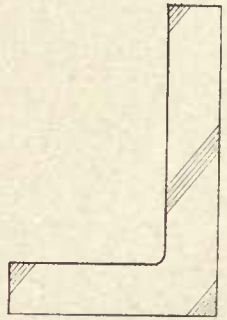


FIG. 74.—A Section on a Penciled Drawing.

In some drafting rooms the sections are "stumped,"—blocked in solid with a soft pencil on the back of the tracing. Others use colored wax crayons, and some "wash them in" with a camel's hair brush and diluted India ink.

CHAPTER VI

MACHINE DRAWING

123. In the representation of machine parts the first consideration is the study of screw threads, bolts, screws, holes and other small details which constitute an essential part of machine construction.

124. Screw Threads. **A screw** is a cylinder around which is an extended portion called a "thread." The thread is constructed on a geometrical curve called a helix. See Fig. 75. The distance between two threads is called the **pitch**; thus, in Fig. 75, the pitch is 1″. If a screw has 8 threads in the space of 1″, the distance between threads, or pitch, is $\frac{1}{8}$. The pitch is also expressed as the number of threads per inch, which in this case is 8; this is the usual method.

125. A section of the screw thread shown in Fig. 75, taken lengthwise, would appear as in Fig. 76. This is called the *thread form* or *profile*. There are several forms of thread in common use, as shown in Figs. 76, 77, 78, and 79.

A standard thread consists of its form, or profile, and definite diameters with certain corresponding pitches.

In this country the "standards" most frequently used are as follows: **United States Standard** (also known as the

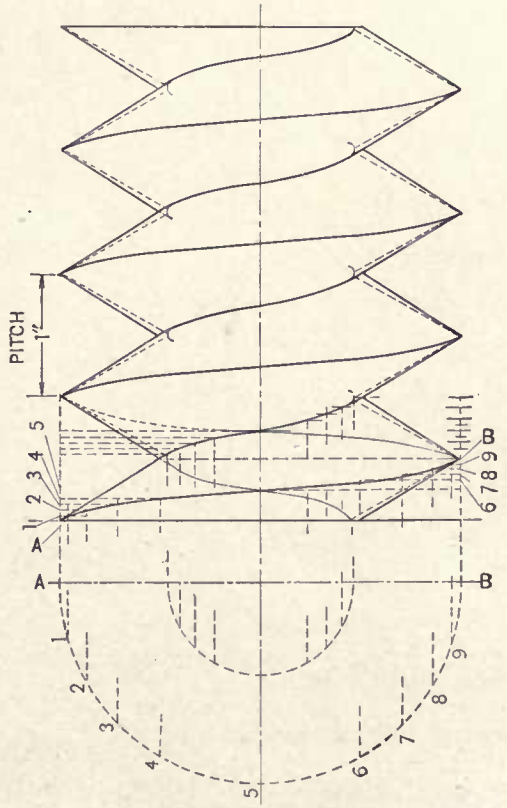


FIG. 75.—A Screw Thread.

Seller's, and Franklin Institute); **Acme Standard; S.A.E. Standard** (for automobile work); **A.S.M.E. Standard;** (machine screw); **Briggs Standard** (for pipe).

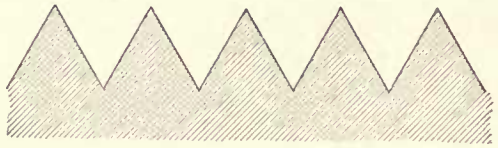


FIG. 76.—V Thread Form or Profile.

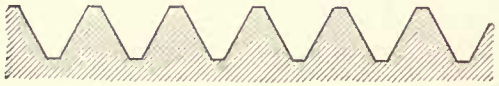


FIG. 77.—U. S. S. Thread Form.

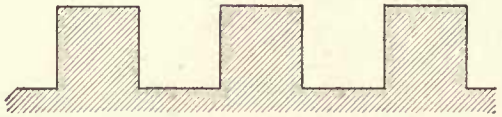


FIG. 78.—Square Thread Form.

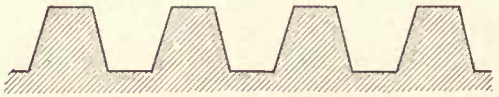


FIG. 79.—Acme Thread Form.

The form of thread in the S.A.E. and A.S.M.E. standards is the same as the U. S. Standard form.

126. In the **representation of screw threads** on working drawings the exact construction of the thread as shown in Fig. 75 would be difficult, laborious, and wholly unnecessary. A system of conventions has been devised and is in general use for the purpose.

A geometrical study of the helix and the "thread parts" are, therefore, not essential to the present discussion and they are left to a more advanced treatment of the subject.

U. S. Standard and V threads should be shown as in Fig. 80; the lines need not be spaced with reference to the pitch of the screw represented.

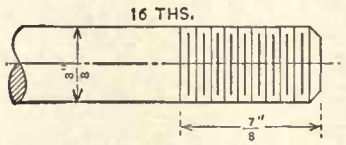


FIG. 80.

FIG. 81.

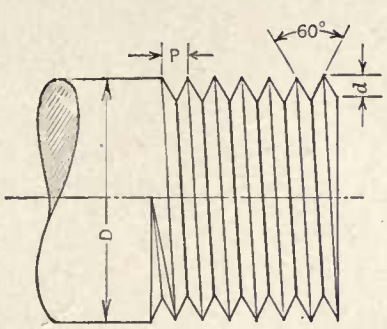
Conventional Representation of V and U. S. S. Threads.

The form of the thread, if other than the usual, should be stated in a note. The diameter, pitch and length of a thread should always be given. If a screw has a left-hand or multiple thread, a note should call attention to the fact.

127. The **conventional thread** shown in Fig. 81 has the sanction of long usage, but that shown in Fig. 80 is advantageous for the following reasons:

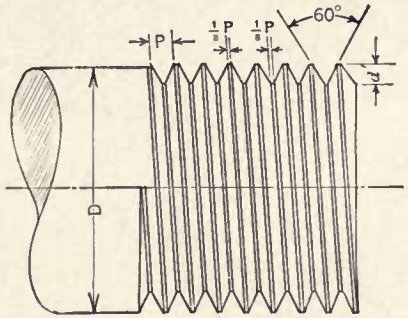
(*a*) It is more easily and therefore more quickly made.

(*b*) The majority of threads are made right-handed. In

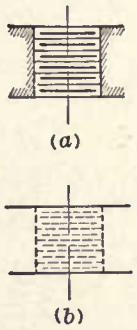


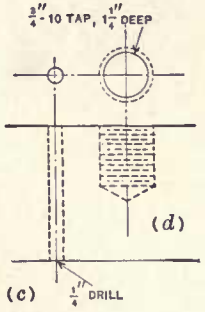
V THREAD, $d = P \times 0.866$

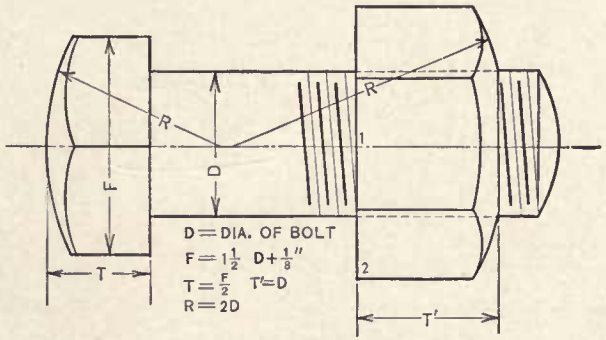
D	THREADS PR. INCH
$\frac{1}{4}$"	20
$\frac{3}{8}$"	16
$\frac{1}{2}$"	13
$\frac{3}{4}$"	10
1"	8
$1\frac{1}{4}$"	7
$1\frac{1}{2}$"	6
$1\frac{3}{4}$"	5
2"	$4\frac{1}{2}$
$2\frac{1}{2}$"	4



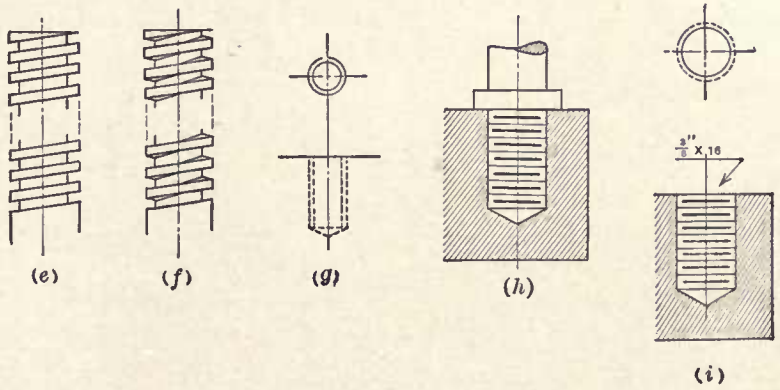
U.S. ST'D THREAD, $d' = \frac{3}{4}d = P \times 0.6495$

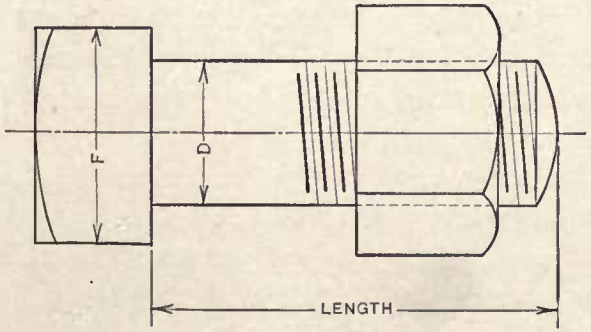




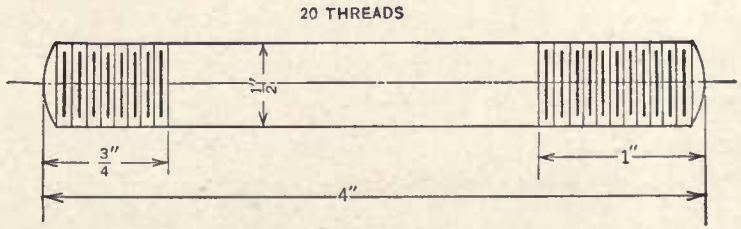


D = DIA. OF BOLT
$F = 1\frac{1}{2}\ D + \frac{1}{8}$"
$T = \frac{F}{2}$ $T' = D$
$R = 2D$





U.S. STANDARD BOLT



STUD BOLT

the absence of other information a right-hand thread is wanted.

(*c*) If a screw has a left-hand or multiple thread the direction of the slant is not a sufficient indication; a note must be used also. A note is sufficient and therefore the slant is unnecessary.

(*d*) A sectional view of a threaded hole shows a right-hand thread having a left slant and vice versa. The opposite slant in either case would be technically wrong and in both uncertain; thus it is better to use no slant and an

FIG. 82.—Thread Conventions sometimes used instead of Figs. 80 and 81.

explanatory note for anything but the usual right-hand thread.

128. The conventions shown in Fig. 82 are sometimes used.

For screws of large diameter the threads are usually represented as shown on Plate X.

Square thread screws should be represented as on Plate X. The lines should be spaced and slanted in accord with the screw shown, unless the drawing is small or the pitch fine. A single thread is designated at (*e*) and a multiple thread at (*f*).

129. Every screw, in order to be effective, requires a corresponding **nut**, i. e., a round hole having an internal thread. A nut may be either movable or stationary. See Fig. 83. The latter is called a "tapped hole." Tapped holes and nuts are shown by the same convention as a screw, the line being broken if invisible. Conventional details of screw threads, bolts, and tapped holes are shown on Plate X.

130. The parts of a bolt are called the *head*, *body*, *thread*, and *nut*.

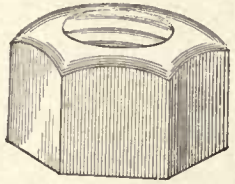


FIG. 83.—A Nut.

A bolt is usually drawn conventionally, one view only being shown. Heads and nuts are generally square or hexagonal in shape; the former is drawn conventionally with one face and the latter with three. Parts such as bolts, screws, etc., that are well represented in one view may be omitted in the others, and only the location need be shown.

131. Bolts and screws other than standard require special drawings as shown in Figs. 84 and 85.

Standard stock bolts, screws and parts used in machine construction are shown on Plate XI. These parts are usu-

ally not detailed, but are specified on the B.M., bolt or stock list. Sizes of screws are designated by the screw gage number and length; bolts are designated by the diameter and length. Ordinarily the length of a bolt is the distance from the point to, but not including, the head.

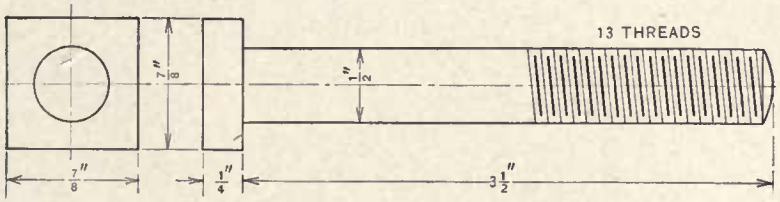


Fig. 84.—Special Bolt.

132. Dimensioning and describing. All the rules previously given for dimensioning working drawings apply to machine drawing, but the character of the latter requires additional information.

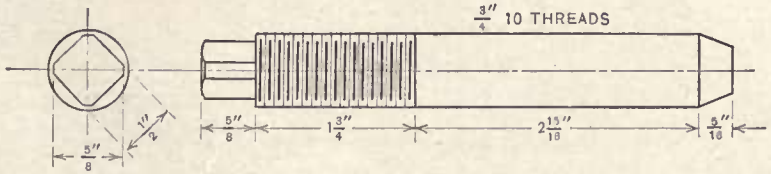


Fig. 85.—A Special Screw.

Some machine parts have to be made with an exactness that requires measurements to be made to thousandths of an inch. Care must be taken in figuring such dimensions and in locating the decimal point. If the dimension is less than one inch, it should be written thus—0.165.

In dimensioning a cylindrical piece, the diameter dimensions should not be placed on the circular view, as they are not so easily read.

133. Drawings of castings should be figured for the machinist, not for the pattern-maker.

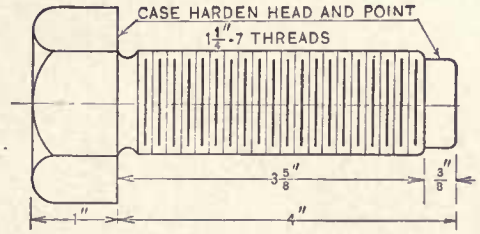


Fig. 86.—Method of Designating a Special Finish.

Forging drawings should always be detailed and, if possible, drawn full size.

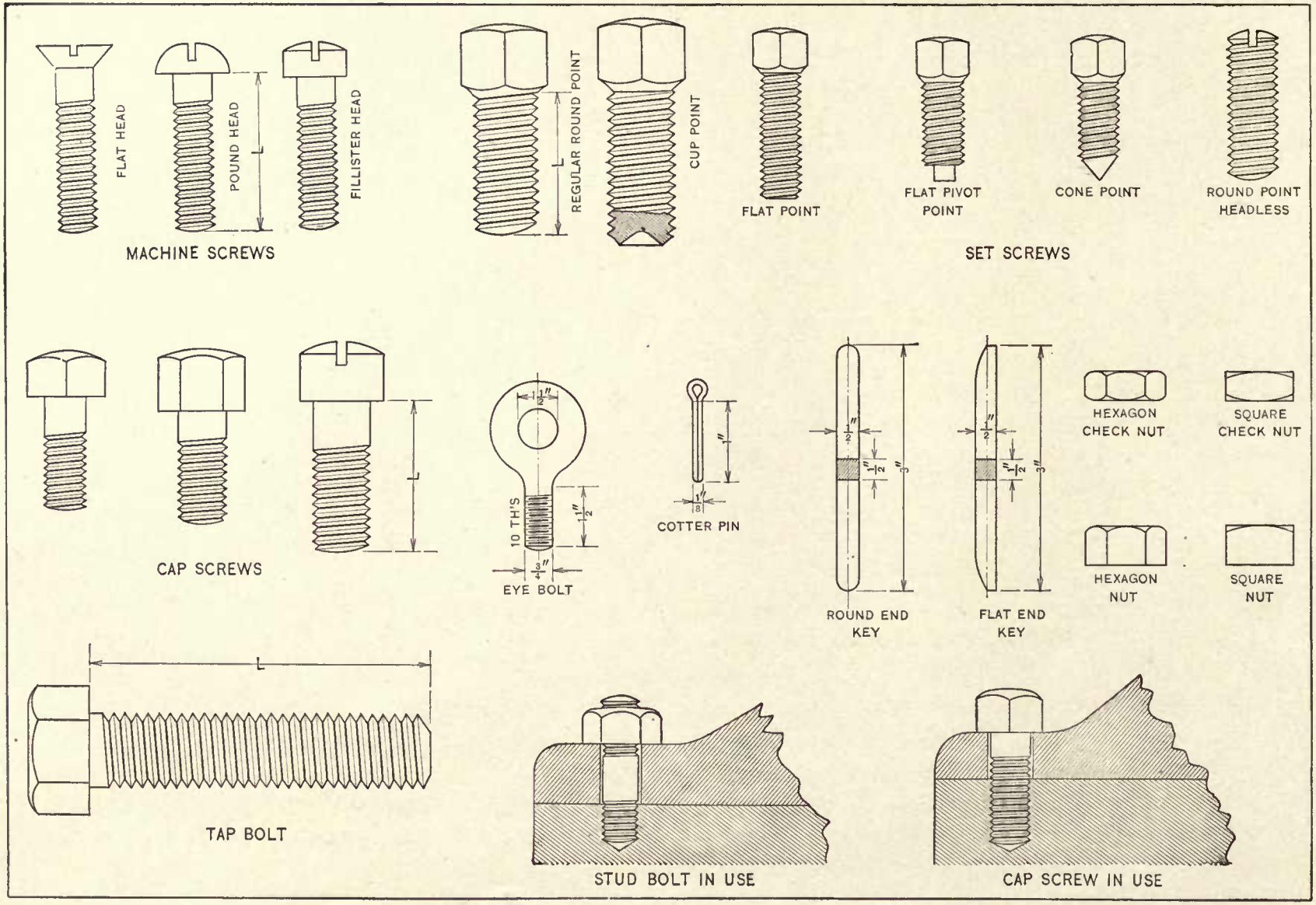
Parts made in rights and lefts require only one drawing with a note, as "Make one each, right and left."

Fig. 87.—Method of Designating a Special Finish.

Similar parts should be dimensioned similarly.

In figuring an angle, use the abbreviation Deg. instead of the sign °.

A dimension which has been changed should be indicated by heavily underscoring the figures, thus, $\underline{4\frac{1}{2}}$"; or by indi-


FLAT HEAD
POUND HEAD
L
FILLISTER HEAD
MACHINE SCREWS
L
REGULAR ROUND POINT
CUP POINT
FLAT POINT
FLAT PIVOT POINT
CONE POINT
ROUND POINT HEADLESS
SET SCREWS
L
CAP SCREWS
10 TH'S
1½"
EYE BOLT
1"
COTTER PIN
ROUND END KEY
FLAT END KEY
HEXAGON CHECK NUT
SQUARE CHECK NUT
HEXAGON NUT
SQUARE NUT
L
TAP BOLT
STUD BOLT IN USE
CAP SCREW IN USE

cating thus, Make $4\frac{1}{2}''$; or thus, "$4\frac{1}{2}''$ Not to scale," or thus, $\frac{4\frac{1}{4}''}{4\frac{1}{2}''}$.

134. Pieces having surfaces that are to be **machine finished** should be designated in the drawing by the letter *f*

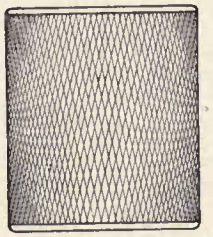


FIG. 88.—Method of Designating a Knurled Surface.

on the projections of the surfaces, or F.A.O. when the finish is to be all over. The dimensions on such pieces should always be for the *finished* size.

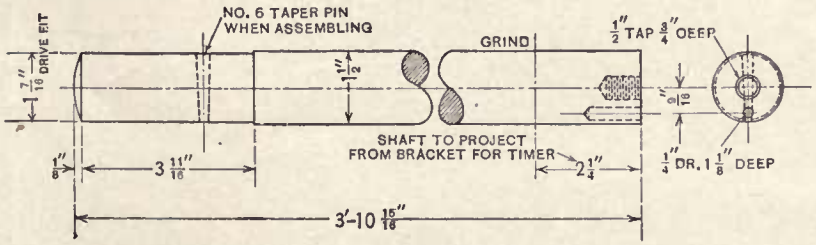


FIG. 89.—Method of Designating a Special Finish.

Special kinds of finish should be specified in a note; e. g., file, polish, scraped, grind, hardened and ground, face, spot face, knurl. See Figs. 86, 87, 88, 89.

Some draftsmen indicate a finished surface by drawing a line in red ink parallel to its projection.

135. The degree of accuracy required and the method of obtaining it are frequently determined by the construction; *e. g., a running fit, a shrink fit, a forced, pressed,* or *drive fit.* See Fig. 89.

136. Holes of various kinds are used in machine construction. Their location and description are important. A

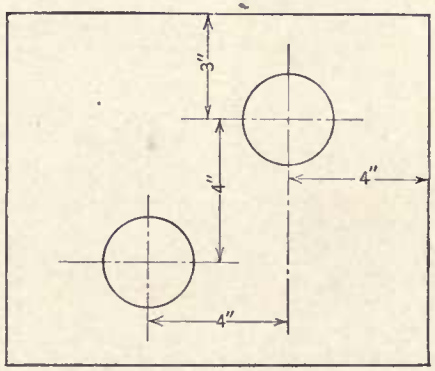


FIG. 90.—Method of Locating Holes.

single hole is located by referring its center to the edges or center lines of the object. Additional holes are tied to the first one, as their *relative locations* are usually important. See Fig. 90.

Bolt holes and similar parts are dimensioned from center to center. If spaced equally and arranged in a circle, give the diameter of the middle circle. See Fig. 91.

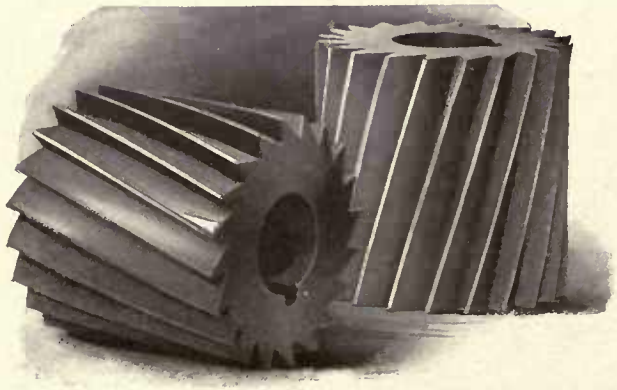
Straight Shank Twist Drill

Taper Shank Twist Drill

Counterbore

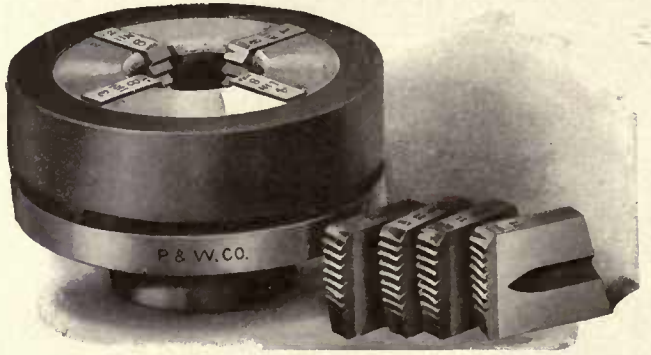
Center Reamers and Counter-sinks

Plain Milling Cutters

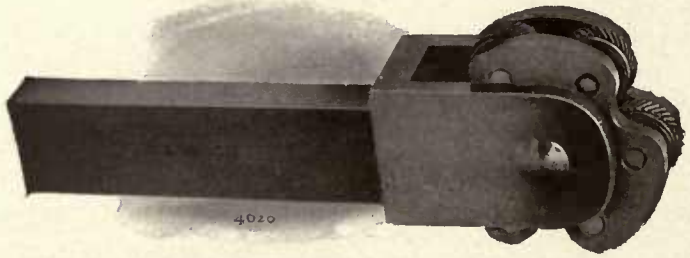


Standard Hand Reamers

Adjustable Die-Stock Die

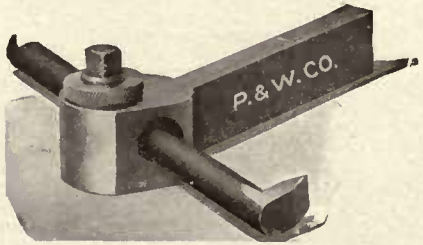


Lathe Knurling Tool



Machinists' Hand Tap

Boring and Inside Threading Tool



NOTE: From the tools shown are derived such terms as—*Drill, Counterbore, Countersink, Mill, Ream, Thread, Knurl, Bore,* and *Tap,* which the draftsman must designate on the drawing.

This method is used for dimensioning flanges, cover plates, and cylinder heads. They are generally shown in section. See Figs. 101 and 102.

Standard flanges are usually represented with "one hole up," if the number of bolts is odd, and with "two holes up"

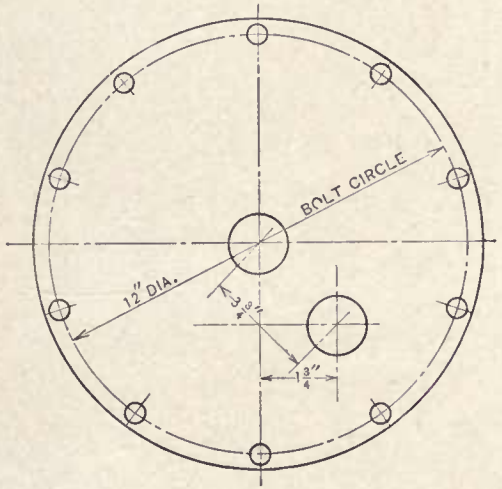


FIG. 91.—Method of Dimensioning Holes in Flanges, Cover Plates, and Cylinder Heads.

if the number is even. In the former case the holes are generally shown in the plane of the section the same as they would be in the latter case. See Fig. 101.

137. Other methods of laying out and spacing holes, including the designation of **cored holes**, are shown in Fig. 92. A **counterbore** is also indicated at *A*.

A **countersunk hole** is shown in Fig. 93.

138. Tools for making and finishing various holes are

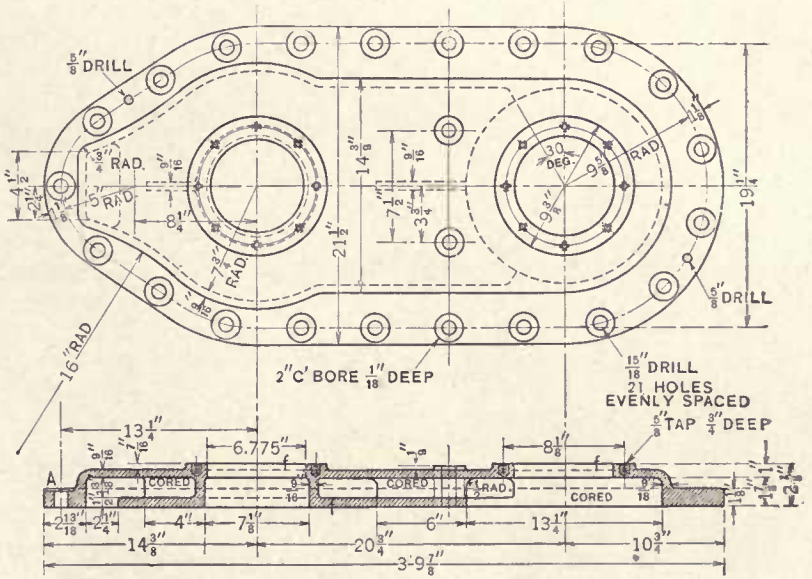


FIG. 92.—Method of Dimensioning the Layout of Holes.

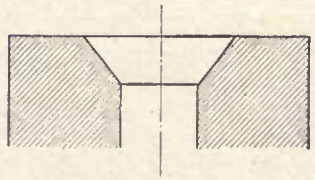


FIG. 93.—Conventional Representation of a Countersunk Hole.

shown on Plate XII. The names of the operations performed are derived from the corresponding tools.

Methods of indicating holes that are to be drilled, bored, reamed, or tapped are shown in Fig. 94.

The layout of the other holes should also be noted.

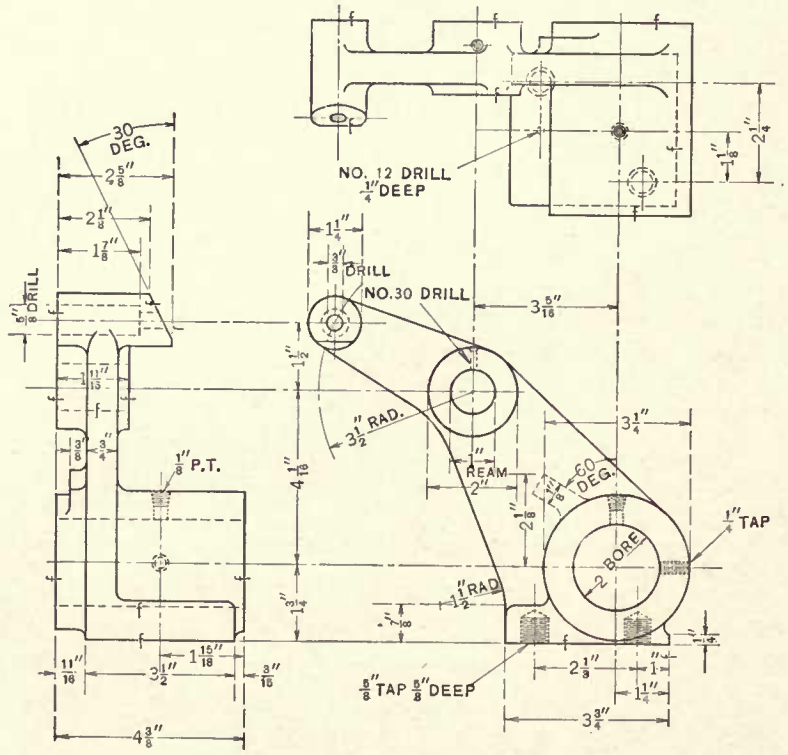


Fig. 94.—Dimensioning and Describing Holes.

139. In dimensioning ordinary **tapers,** such as keys, they may be indicated as in Fig. 95. Any of the methods shown may be used.

A standard taper is designated as in Fig. 96.

A taper with a steep pitch should be indicated by the degrees to which the grinder head is set. See Fig. 97.

The taper for a rod end is shown in Fig. 98.

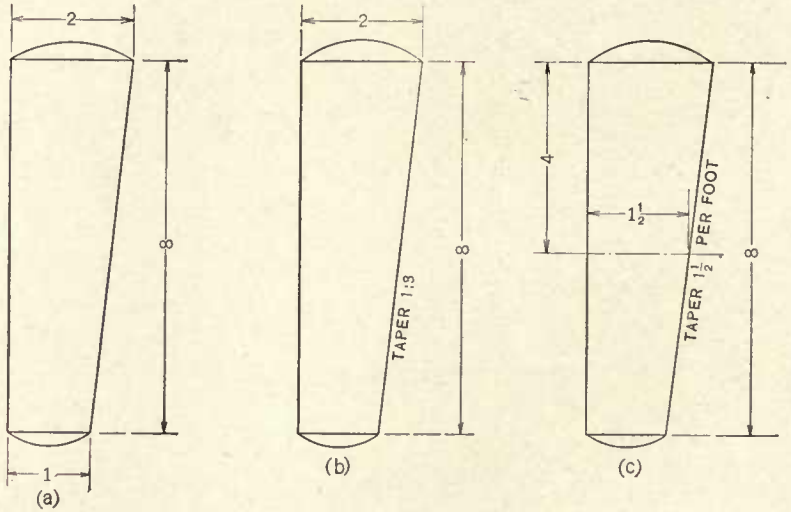


Fig. 95.—Dimensioning Ordinary Tapers.

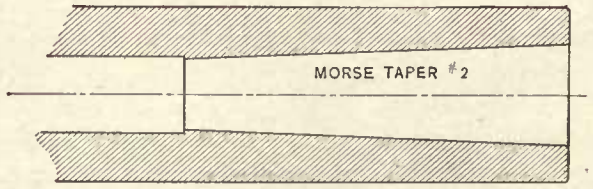


Fig. 96.—Dimensioning a Standard Taper.

140. Shafts are dimensioned as shown in Fig. 99; see also Fig. 89. Diagonals indicate the location of **bearings.**

A long screw is shown in Fig. 100.

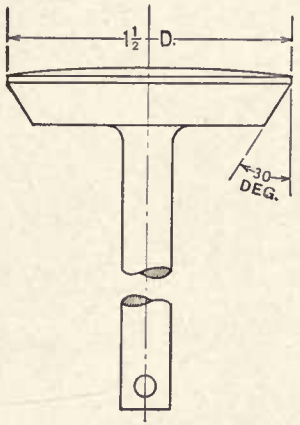


FIG. 97.—Dimensioning a Steep Taper.

It is not necessary to draw threads the full length.

141. Sections. Sectional views of machine parts are

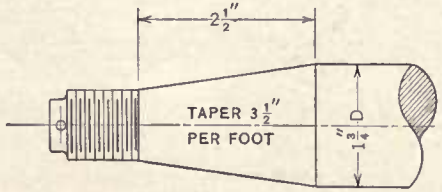


FIG. 98.—Dimensioning the Taper of a Rod End.

made according to the same general principles that were explained in connection with working drawings. There are some features, however, which are characteristic of this class of work that require further consideration.

In some cases parts lying in the plane of the section are not sectioned or are omitted altogether. It is not usual to

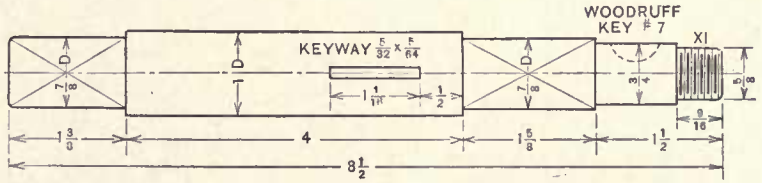


FIG. 99.—Dimensioning a Shaft.

section bolts, standard nuts, screws, shafts, keys, arms of wheels (lengthwise), ribs, gear teeth, etc.

This is illustrated in Figs. 101 and 106.

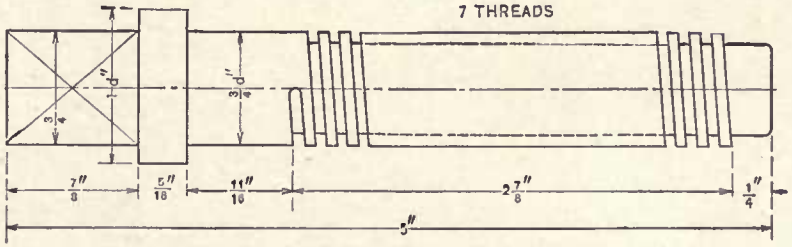
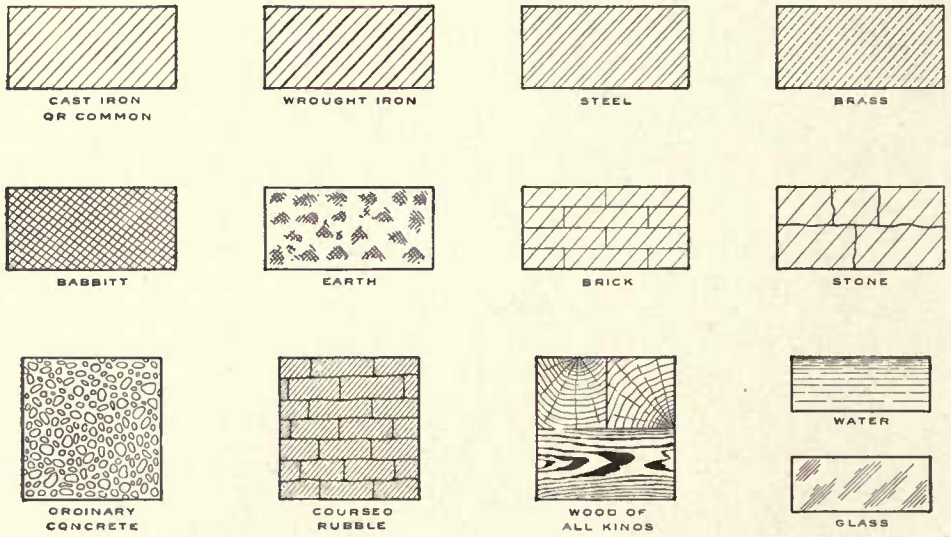
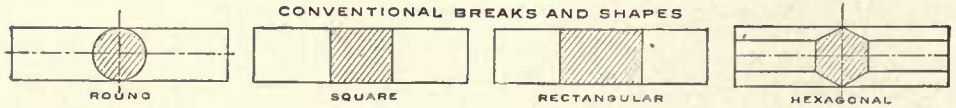


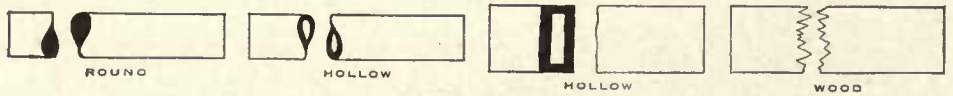
FIG. 100.—Dimensioning a Long Screw.

142. In Fig. 101 the section of the cover is represented conventionally by showing the bolts revolved into the plane of the section. They may also be shown as in Fig. 102. In the latter case the bolts are shown in their true distance, not projected, from the center.



CONVENTIONAL BREAKS AND SHAPES

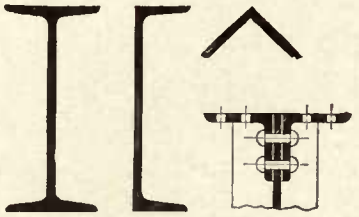


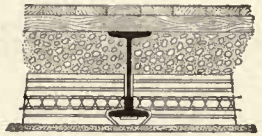


STRUCTURAL SHAPES

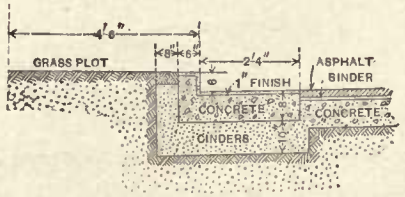
ABBREVIATIONS

Cast Iron	C.I.
Wrought Iron	W.I.
Malleable Iron	Mal.I.
Cast Steel	C.S.
Cold Rolled Steel	C.R.S.
Machine Steel	M.S.
Steel Forging	S. Forg.
Steel Tube	S. Tube
Brass	Br.
Bronze	Brz.
Phosphor Bronze	Ph.Brz.
Fiber	Fbr





64 POUNDS PER SQUARE FOOT
10-INCH I BEAM



143. A **dotted section** is shown in Fig. 103. It is used in cases where it is desired to retain the full exterior view. If the section area is large the outline only may be dotted.

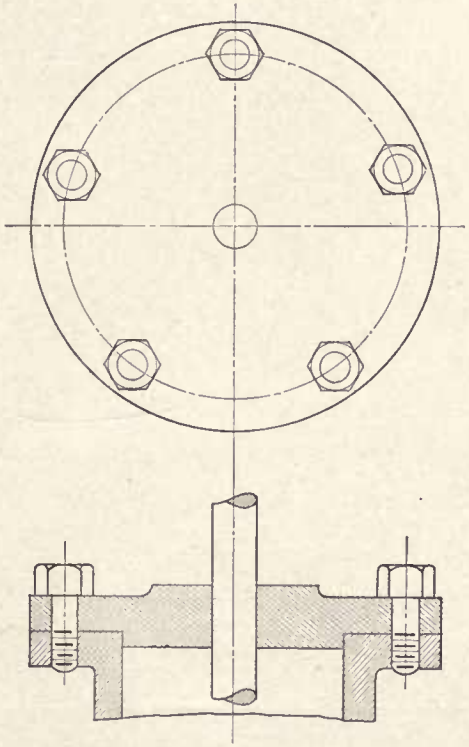


FIG. 101.—Conventional Section of a Cover or Cylinder Head.

A **partial section** is shown in Fig. 104.

Sections with narrow surfaces are usually blocked in solid. See Plate XIII, I beam and structural steel.

144. A section of a **symmetrical piece** should be made symmetrical. The section of a pump valve, shown in Fig.

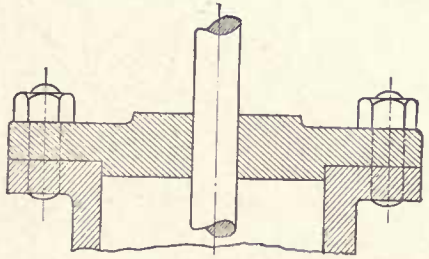


FIG. 102.—Conventional Section with Bolts Represented as Invisible.

106, illustrates this principle. A true projected section of the valve seat would appear as in Fig. 107. It is readily

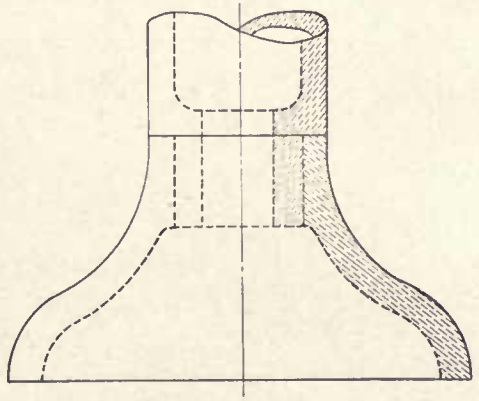


FIG. 103.—A Dotted Section.

seen that the section as shown is misleading, as it conveys no idea of the symmetry of the piece, and it is also difficult

of interpretation, whereas the conventional section is easily understood.

145. A section of a part having a rib may be drawn as at A, Fig. 108, which shows the valve seat of Fig. 106. It may also be represented by a revolved section as shown at B.

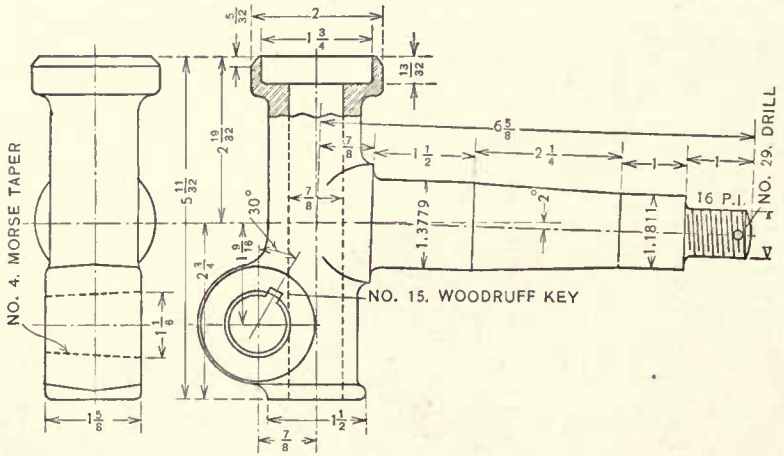


FIG. 104.—A Partial Section.

146. The **material** of which a piece is made is often represented by a conventional section line. See Plate XIII.

The shape of a piece may also be shown by a conventional break or section, as a shaft, a pipe, or a bar. See Plate XIII.

Long pieces are represented in this manner. See Fig. 89. They are also represented by the method shown in Fig. 109.

147. **Pulleys** and **gears** are represented conventionally, the face view usually being in section. See Fig. 110. The

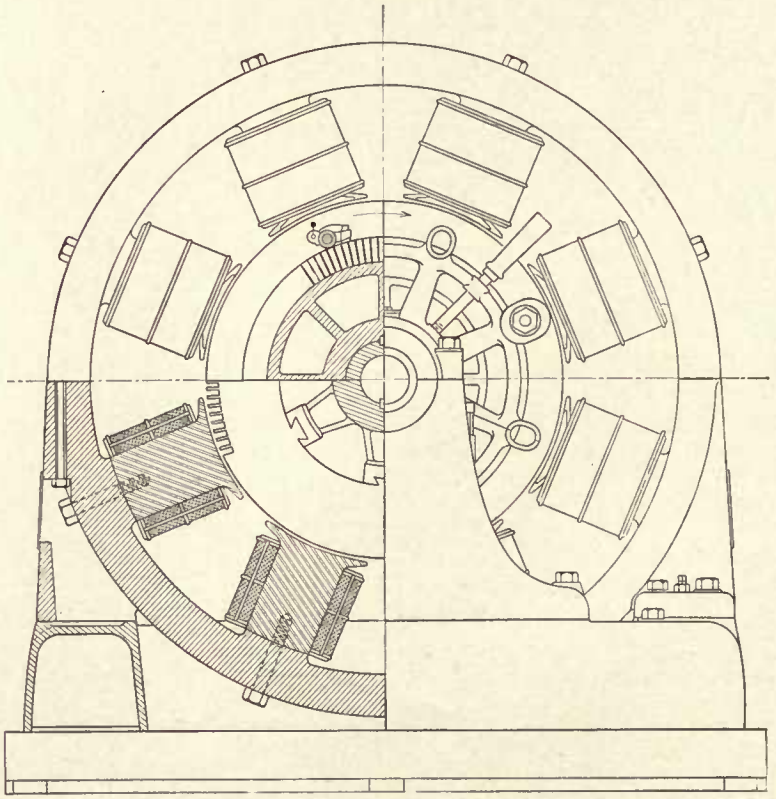


FIG. 105.—A Discontinuous Section.

parts of a pulley are the *rim* and *spider*. The outside of the rim is called the *face*, which is made either "straight" or

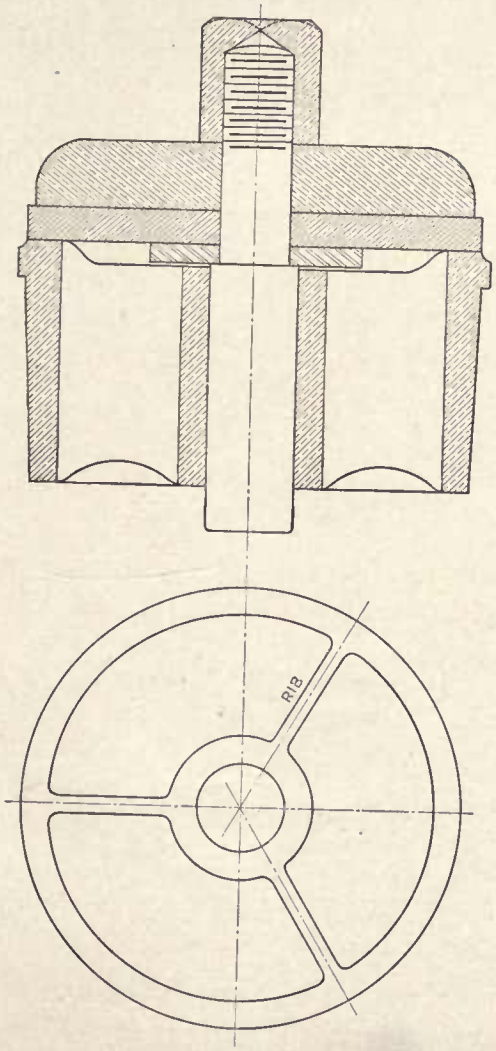


FIG. 106.—A Section of a Symmetrical Piece.

"crowned." The spider includes the *arms* and *hub*. The hole in the hub is called the *bore*. The size of a

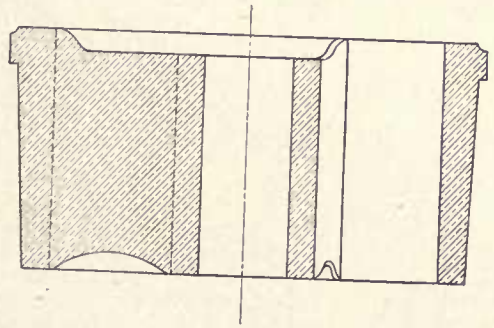


FIG. 107.—A True Projected Section of Fig. 106.

pulley is designated by the diameter, width of face, and bore.

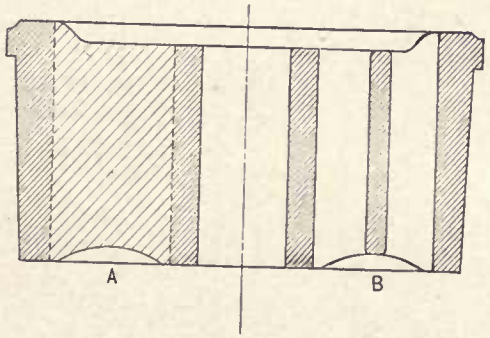


FIG. 108.—Methods of Sectioning Ribs.

Pulleys and gears are secured to the shaft by set-screws or keys, or in the case of "split" pulleys, by compression.

Keyways are frequently shown dotted, i. e., behind the section, thus avoiding an unequal thickness of section in the hub which might cause a shop error.

A "web" pulley has no arms, but is cast solid. Conventional gears are shown in Figs. 111 and 112.

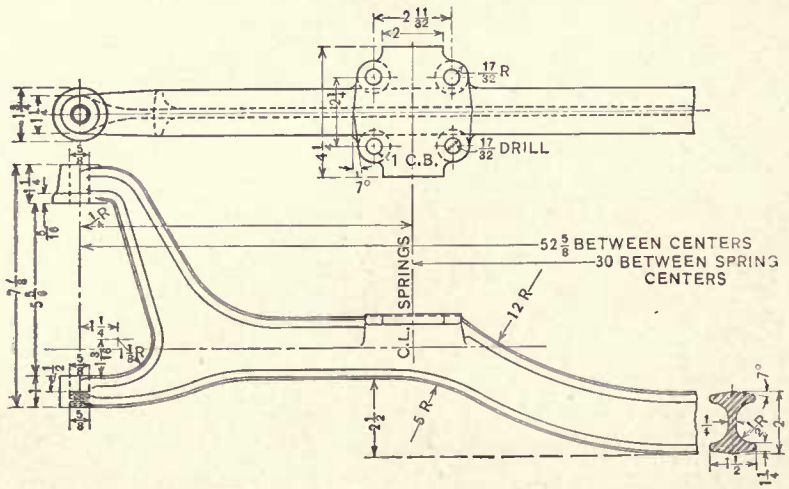


FIG. 109.—A Section of a Long Piece.

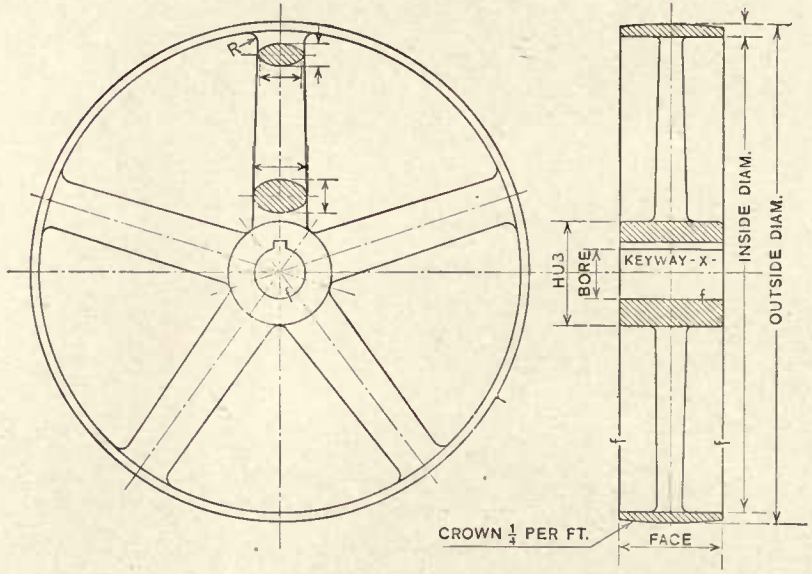


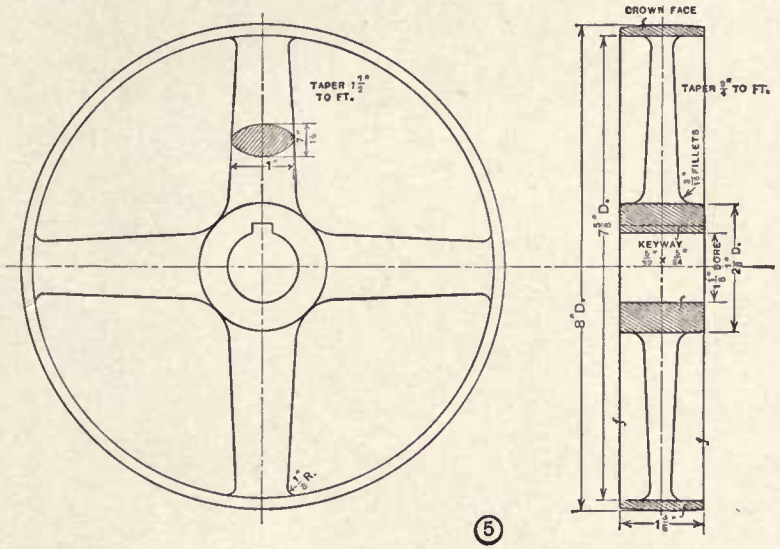
FIG. 110.—Conventional Section of a Pulley.

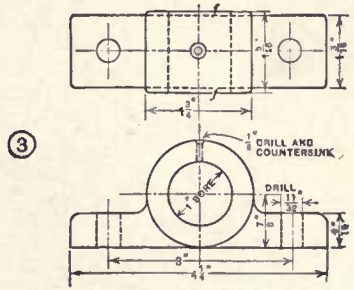
148. Titles. Each drawing should bear a title placed in the lower, right-hand corner. The title should state the name of the object, the scale, the name and location of firm, the date, and the name of the draftsman.

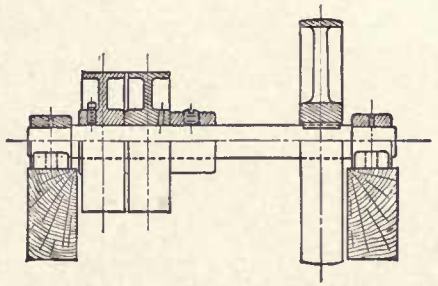
Titles of details should appear under the drawings of the same and should include the name or number of the part, the scale, finish—if F.A.O., and the pattern or list number if any. See Plate V.

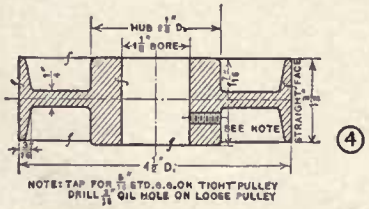
Sizes or names, pattern, list, or forging numbers are not to be placed on assembly drawings, except when details are built from these drawings.

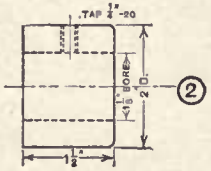
Machines having a large number of parts usually require a separate B.M., a list of stock or standard parts, or a bolt list.

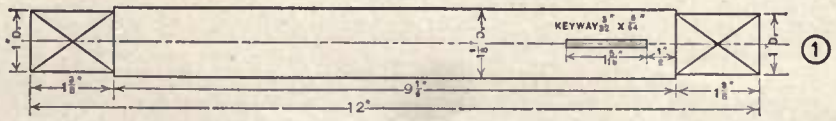












BILL OF MATERIAL				
MARK	NAME	NO. REQ.	MAT'L	REMARKS
	STD. S.S.	1	STEEL	5/16" X 3/4" LONG
	STD. S.S. HDLS.	1	STEEL	1/4" X 7/16" LONG
	KEY	1	STEEL	5/32" SQ. X 7/16" LONG
5	PULLEY, ARM	1	C. IRON	PAT. NO. 4
4	PULLEY, WEB	2	C. IRON	1 EA. T & L PAT. NO. 2
3	BEARING	2	C. IRON	PAT. NO. 5
2	COLLAR	1	C. IRON	F.A.O. PAT. NO. 2
1	SHAFT	1	M.S.	F.A.O.

DETAILS

COUNTERSHAFT

M.D. DEPT. INSTITUTE

CITY STATE

SCALE

DATE NAME

APPROVED

A general drawing of machine details is shown on Plate XIV.

149. Checking a drawing. It is very important that every drawing should be carefully checked. Students should practice by checking each other's drawings. To be effective, checking must be done systematically; the following scheme will be found helpful:

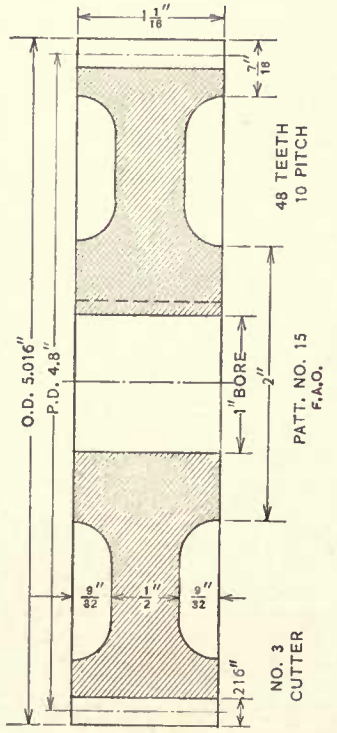


Fig. 111.—A Conventional Small Gear, or Pinion, with Web.

1. Views:
   - *a.* Selection.
   - *b.* Arrangement.
   - *c.* Center lines.
2. Scale.
3. Projections:
   - *a.* Outlines—visible and invisible.
   - *b.* Details.
4. Sections.
5. Conventions and standards.
6. Dimensions:
   - *a.* Placing.
   - *b.* Necessary—length, breadth, thickness, location.
   - *c.* Arrowheads and witness marks.
   - *d.* Figures—by scaling and computation.
   - *e.* Clearances.
7. Finish Marks.

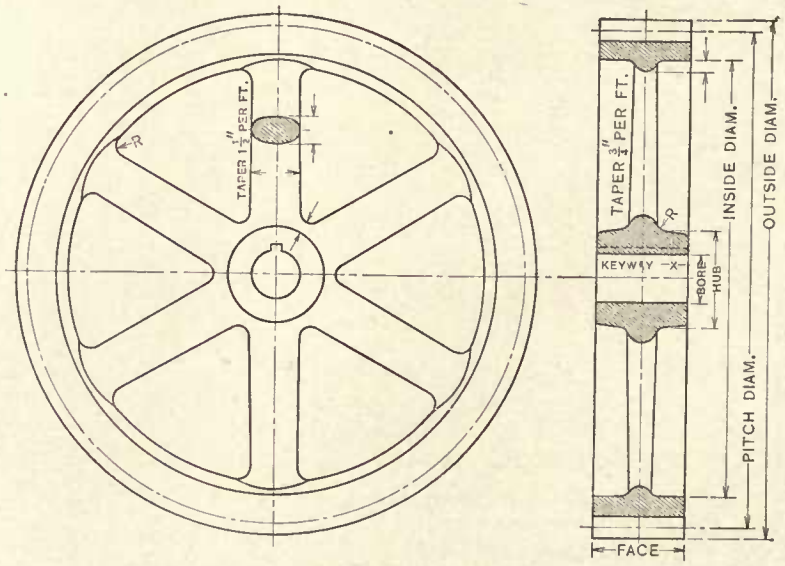


Fig. 112.—A Conventional Gear with Spider.

8. Notes.
9. Bill of material.
   Quantities, kinds, sizes, stock parts.
10. Title.

CHAPTER VII

PLAN DRAWING

150. Kinds of Drawings. Plans are drawings which show the arrangement of the rooms, the exterior, and the construction of a building. The first are called *floor plans*, the second *elevations*, and the last *details*.

A simple floor plan is shown in Fig. 113. Note the conventional method of indicating the size of the rooms, and the position and size of the openings; i.e., the windows and the doors.

A floor plan is in reality a horizontal section taken just above the window sill, but the space occupied by the walls is either left blank or is blocked solid, and no attempt is made to represent the actual section.

151. An elevation is shown in Fig. 114. It represents the exterior features, proportions, arrangement, and finish of the building.

A section, as the name implies, shows the interior in elevation. Its purpose is to secure the proper heights and proportions for the openings and wall spaces, good arrangement, clearances in stairs, plumbing, etc.

Floor plans and elevations are drawn to a scale of $\frac{1}{8}''$ or $\frac{1}{4}''=1'$. It is not practicable to show on a drawing to so small a scale the various details of construction, such as framing joints, window and door frames, cupboards,

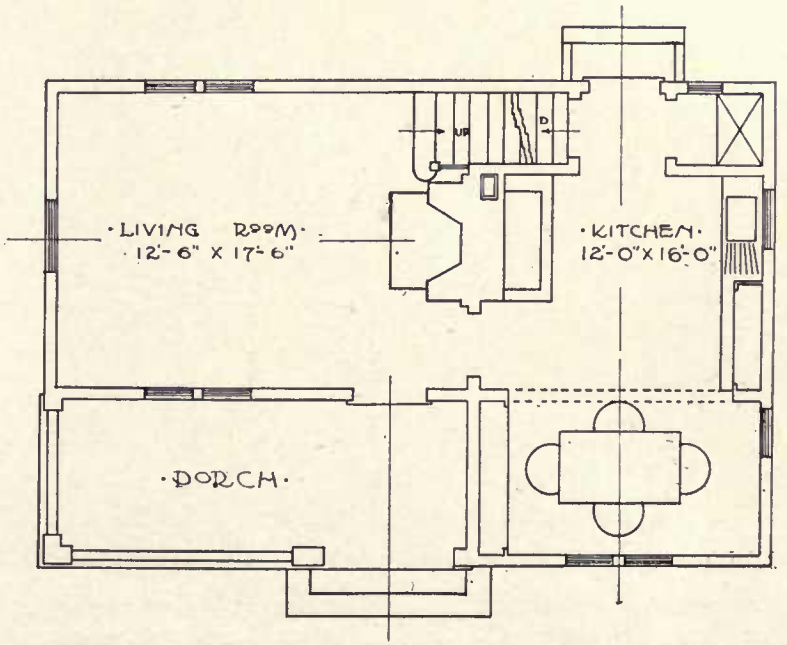


FIG. 113.—A Simple Floor Plan.

cornices, trim, moldings, etc., and it is therefore necessary to make the drawings of these features to a larger scale.

152. Detail drawings are made to scale full size or to as large a scale as circumstances will allow. Generally they do not represent the whole object, various sections and parts being shown instead. See Plate XV.

FIG. 114.—An Elevation.

153. A perspective drawing is often made for the purpose of conveying to the owner a pictorial idea of the finished building. Perspectives are rendered in "pen and ink," or "wash" drawings. The latter is done with a brush. The former is shown on Plate XV.

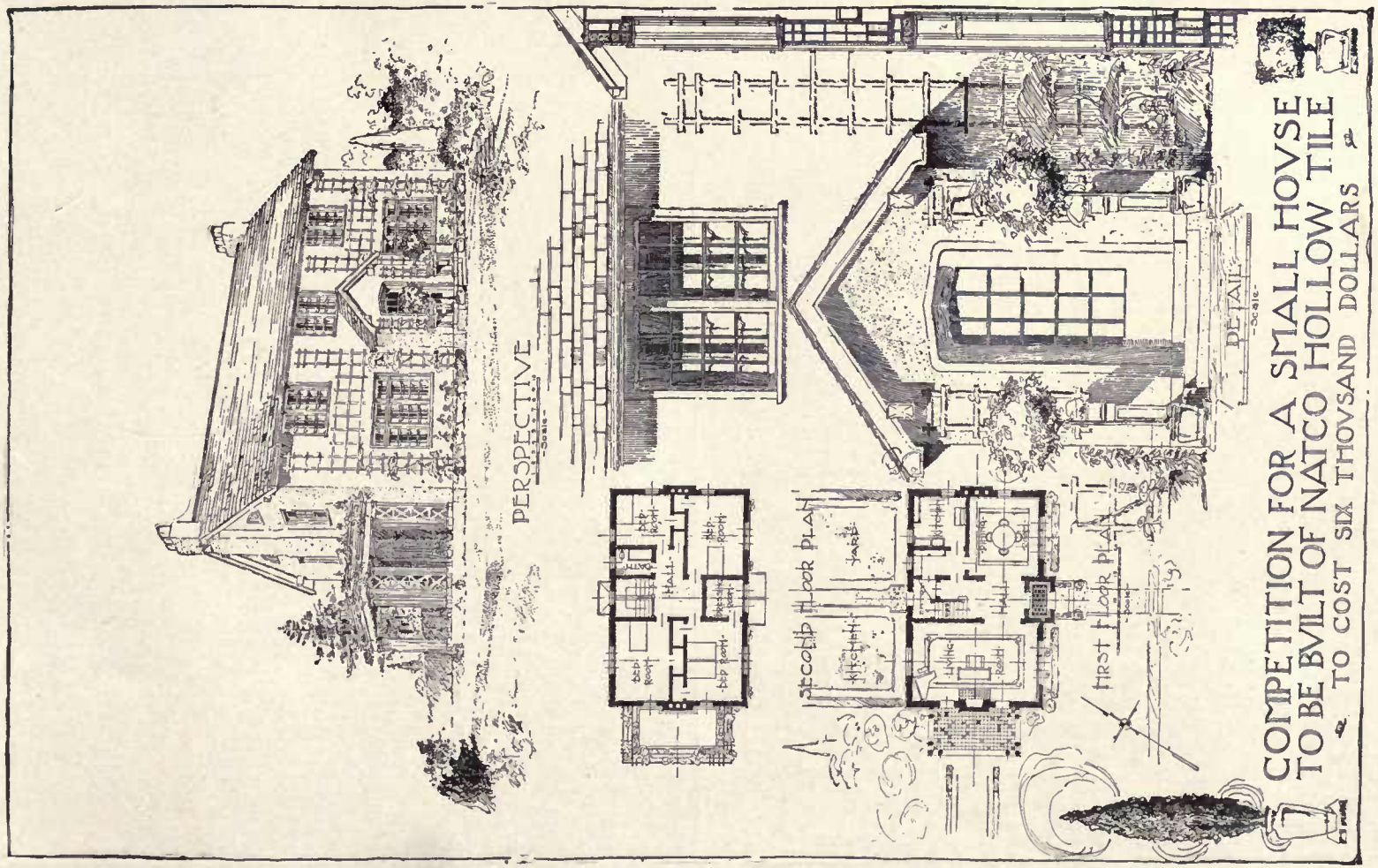
154. Conventions, or symbols, are used on plan drawings for the purpose of representing walls, doors, windows and

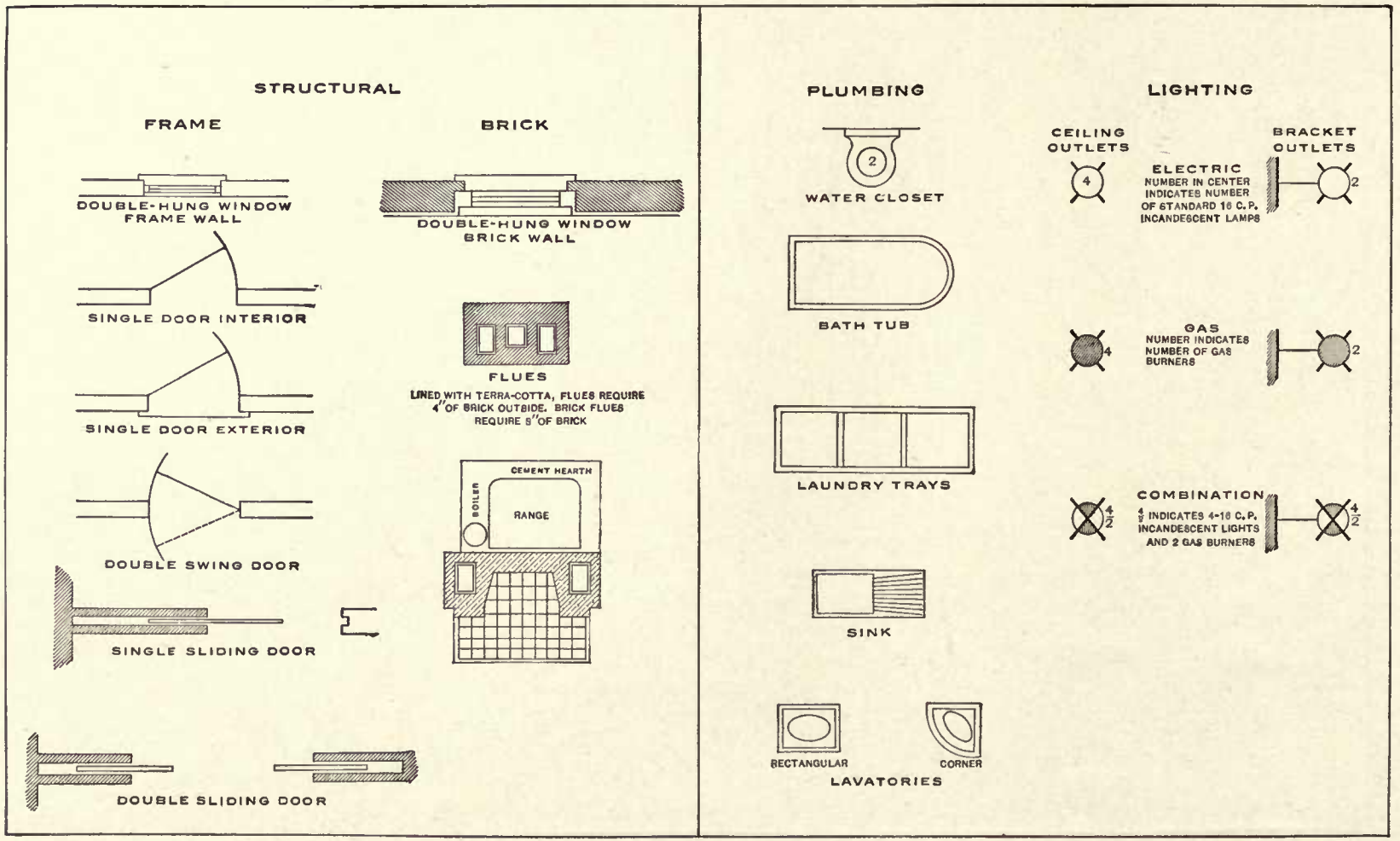
ALPHABET
FOR
ARCHITECTURAL
DRAWING
ABCDEFGHIJKLMNOP
QRSTUVWXYZ&
1234567890

LETTERING
SHOULD BE UNIFORM

LETTERS MAY BE
PROPORTIONED TO FIT
THE GIVEN SPACE

FIG. 115.


COMPETITION FOR A SMALL HOUSE
TO BE BUILT OF NATCO HOLLOW TILE
TO COST SIX THOUSAND DOLLARS
PERSPECTIVE
DETAIL
SECOND FLOOR PLAN
FIRST FLOOR PLAN


STRUCTURAL
FRAME
BRICK
DOUBLE-HUNG WINDOW FRAME WALL
DOUBLE-HUNG WINDOW BRICK WALL
SINGLE DOOR INTERIOR
FLUES
LINED WITH TERRA-COTTA, FLUES REQUIRE 4" OF BRICK OUTSIDE. BRICK FLUES REQUIRE 8" OF BRICK
SINGLE DOOR EXTERIOR
CEMENT HEARTH
BOILER
RANGE
DOUBLE SWING DOOR
SINGLE SLIDING DOOR
DOUBLE SLIDING DOOR
PLUMBING
WATER CLOSET
BATH TUB
LAUNDRY TRAYS
SINK
RECTANGULAR
CORNER
LAVATORIES
LIGHTING
CEILING OUTLETS
BRACKET OUTLETS
ELECTRIC
NUMBER IN CENTER INDICATES NUMBER OF STANDARD 16 C.P. INCANDESCENT LAMPS
GAS
NUMBER INDICATES NUMBER OF GAS BURNERS
COMBINATION
4/2 INDICATES 4-16 C.P. INCANDESCENT LIGHTS AND 2 GAS BURNERS

other features of construction. The more important of these are shown on Plate XVI.

155. The lettering is an important feature of plan drawing. The fundamental principles and rules for the construction of letters are the same as explained in Chapter II. The form, however, is quite different, the aim being to secure a more artistic effect. There are many styles in use; a simple one is shown in Fig. 115.

156. Construction of a Building. Some knowledge of the structural features of a building is essential in order to be able to draw plans properly. There are several types of construction, such as frame, brick, stone, hollow tile,

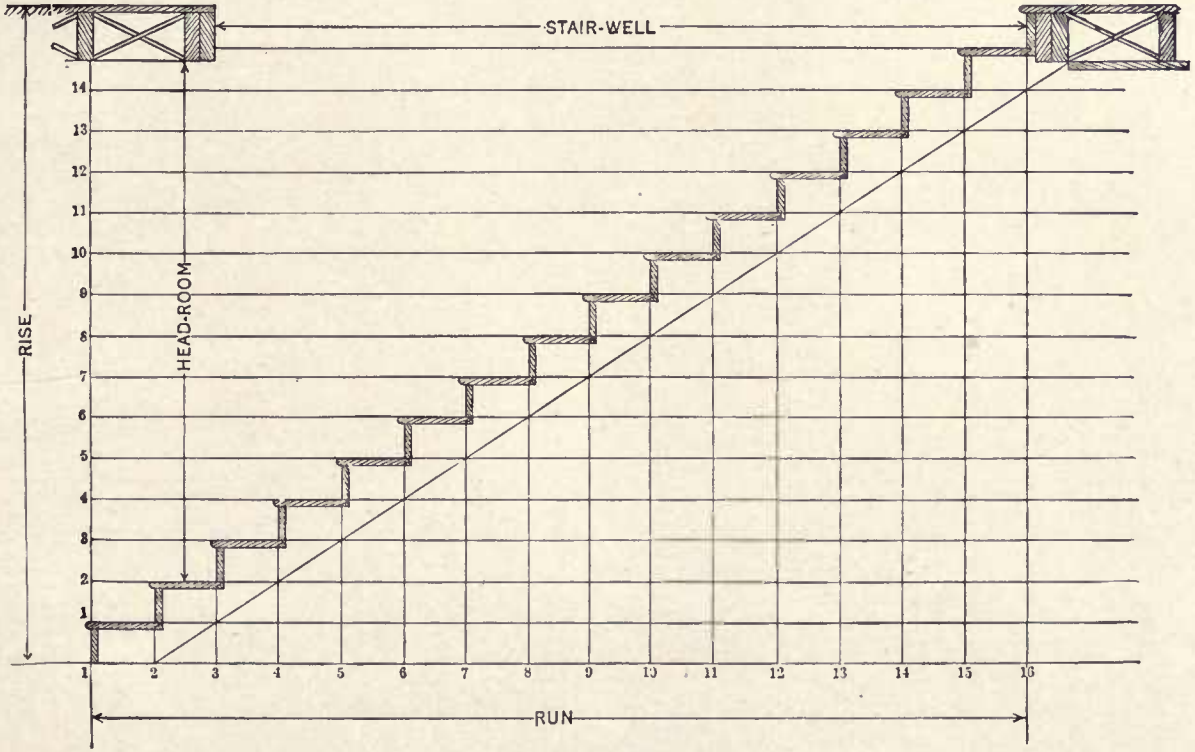
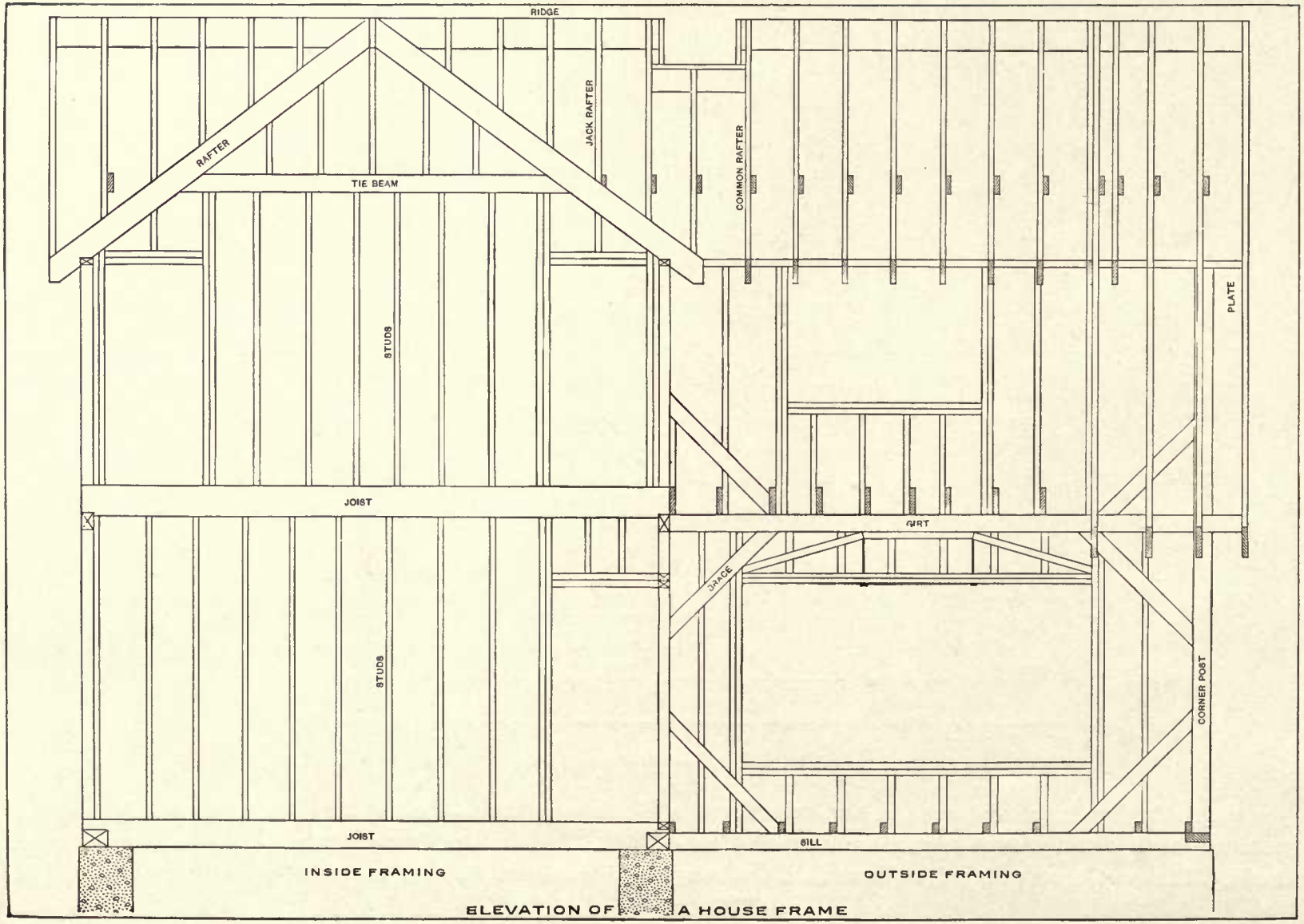
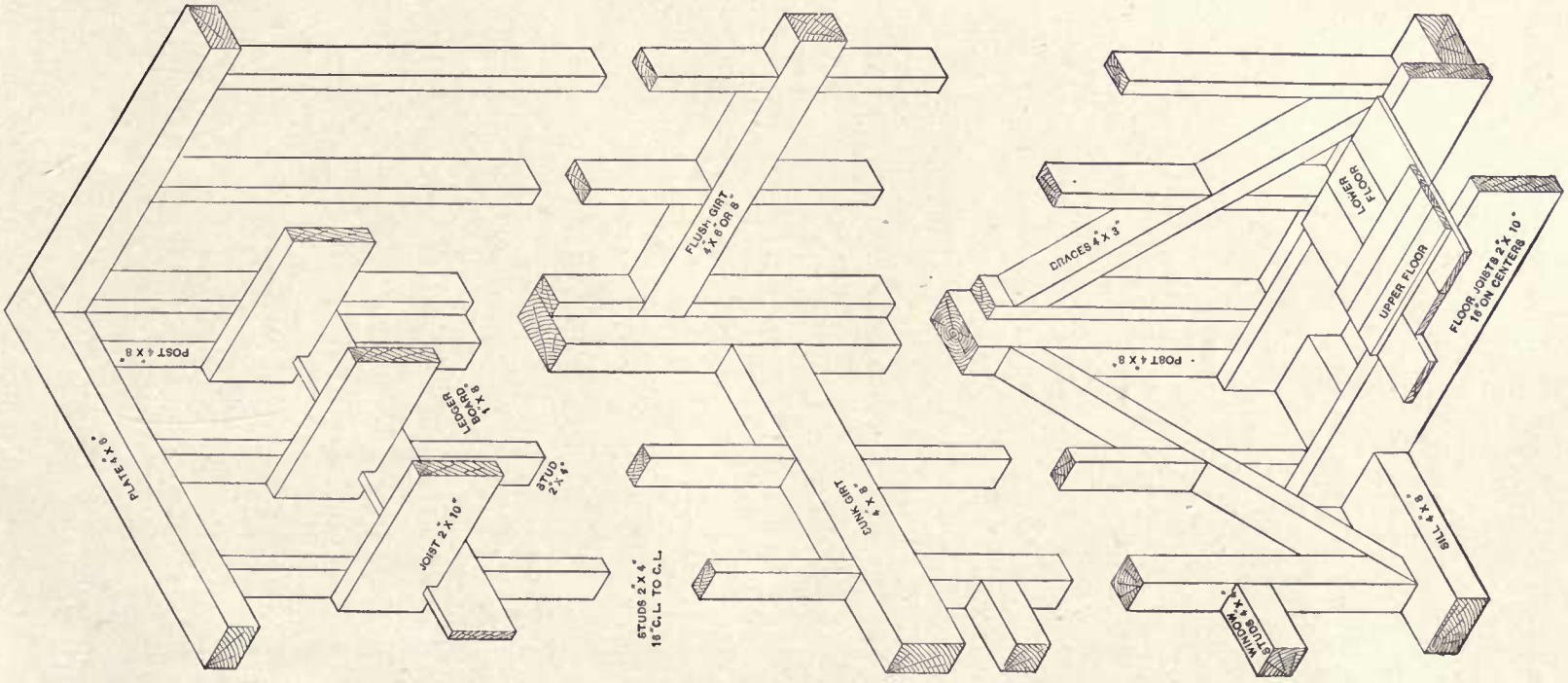


Fig. 116.—Stair Arrangement.



ELEVATION OF A HOUSE FRAME


POST 4 X 8"
PLATE 4" X 6"
LEDGER BOARD 1" X 6"
STUD 2" X 4"
JOIST 2" X 10"
STUDS 2" X 4" 16" C. L TO C. L
FLUSH GIRT 4" X 6" OR 8"
GUNK GIRT 4" X 8"
BRACES 4" X 8"
LOWER FLOOR
UPPER FLOOR
FLOOR JOISTS 2" X 10" 16" ON CENTERS
POST 4 X 8"
SILL 4" X 8"
WINDOW STUDS 4" X 4"

NOTE: There is no standard of details in framing, practice varies widely, but in a locality the construction is generally uniform. This illustration is shown for the purpose of defining terms and showing structural units and relations rather than to exhibit a definite structure.

and concrete. The frame type should first be studied and understood by the student, not only on account of its prevalence, but also because it is fundamental and the others are readily understood from it.

157. A building frame is made of rough timbers and rests upon a foundation of stone, concrete, brick, or hollow

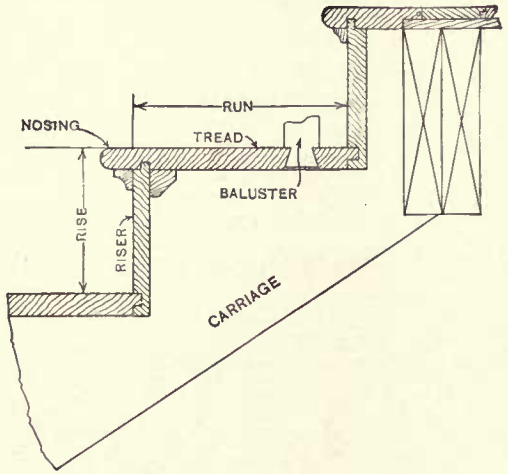


FIG. 117.—Details of Stair Construction.

tile. See Plate XVII. The names of the members and their relations should become familiar to the student. A corner of a frame is shown to a larger scale on Plate XVIII.

The frame of the building is covered on the inside and outside with finishing materials as shown on Plate XIX.

The construction as indicated on these plates represents the average customary practice in as simple a form as possible. The materials and methods of building construction are usually standardized to a large extent in given localities; this refers not only to sizes of timbers, framing, and details, but also to plumbing, finish, and even to style. The fundamental principles, however, are the same everywhere and drawings may be varied to conform with local requirements.

158. The construction of a window and door and their corresponding openings is shown on Plates XX and XXI. The details vary as was stated in the preceding paragraph.

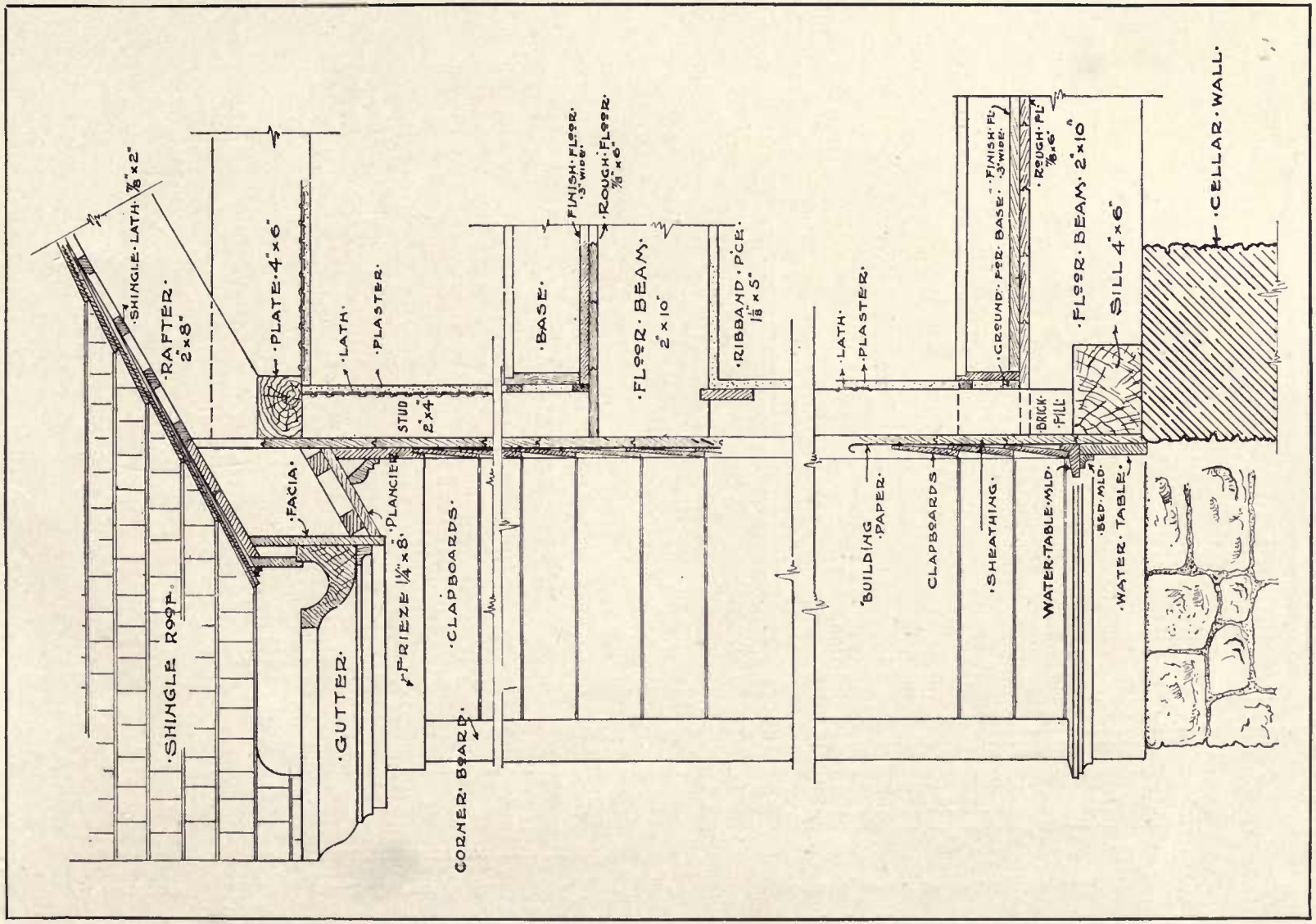
The window and door casings, base, moldings, chair and plate rails, and all other interior finish in wood are designated generally as the *trim*.

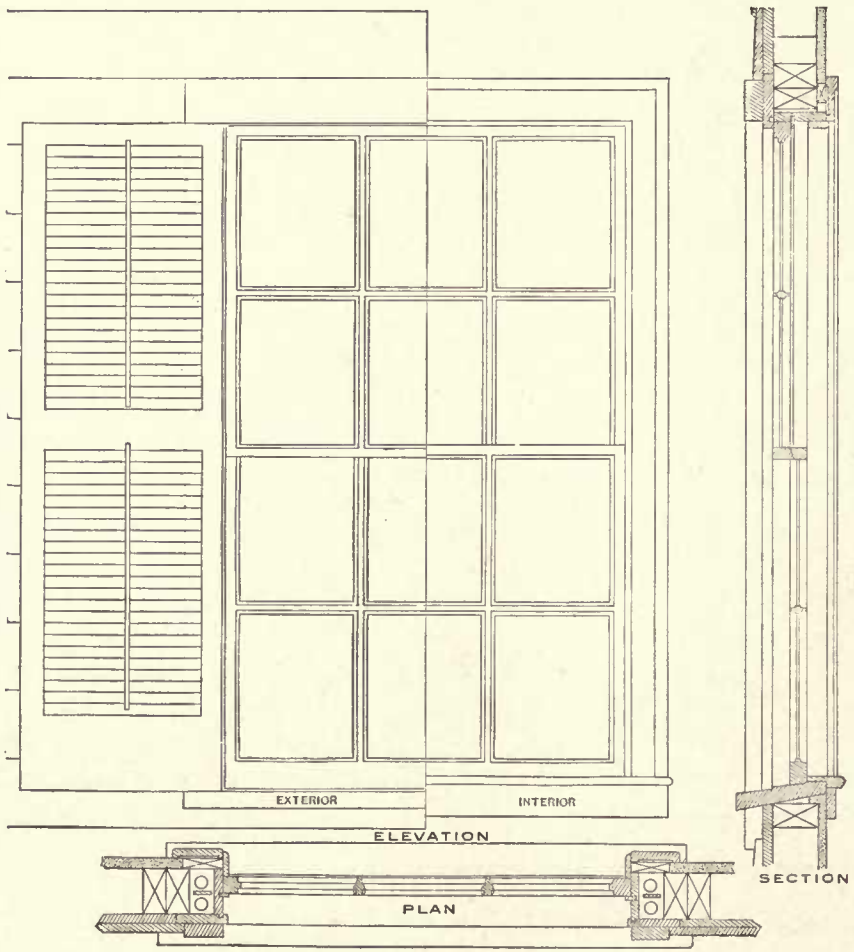
159. The stairs are an important factor in the building. In addition to their utility they may often be treated with artistic effect.

A straight run of stairs is known as a *flight*, see Fig. 116. Details of construction are shown in Fig. 117. In laying out the stairs, sufficient head room must be provided and the whole staircase requires careful planning.

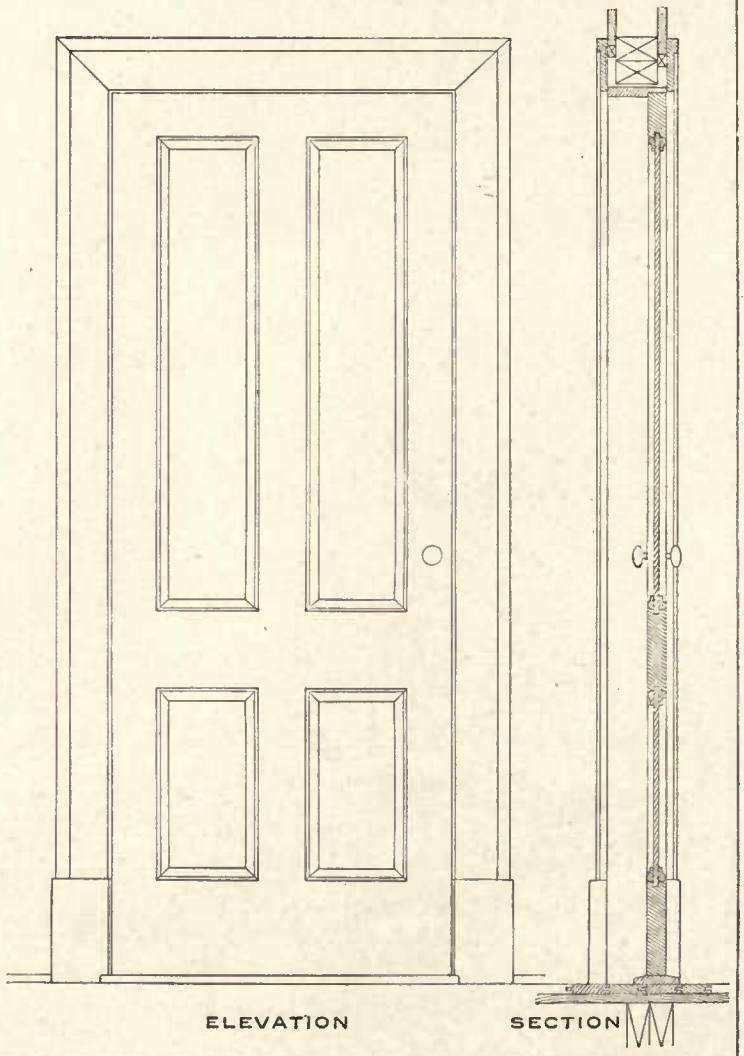
160. Chimney construction and a detail of a fire-place are shown in Fig. 118.

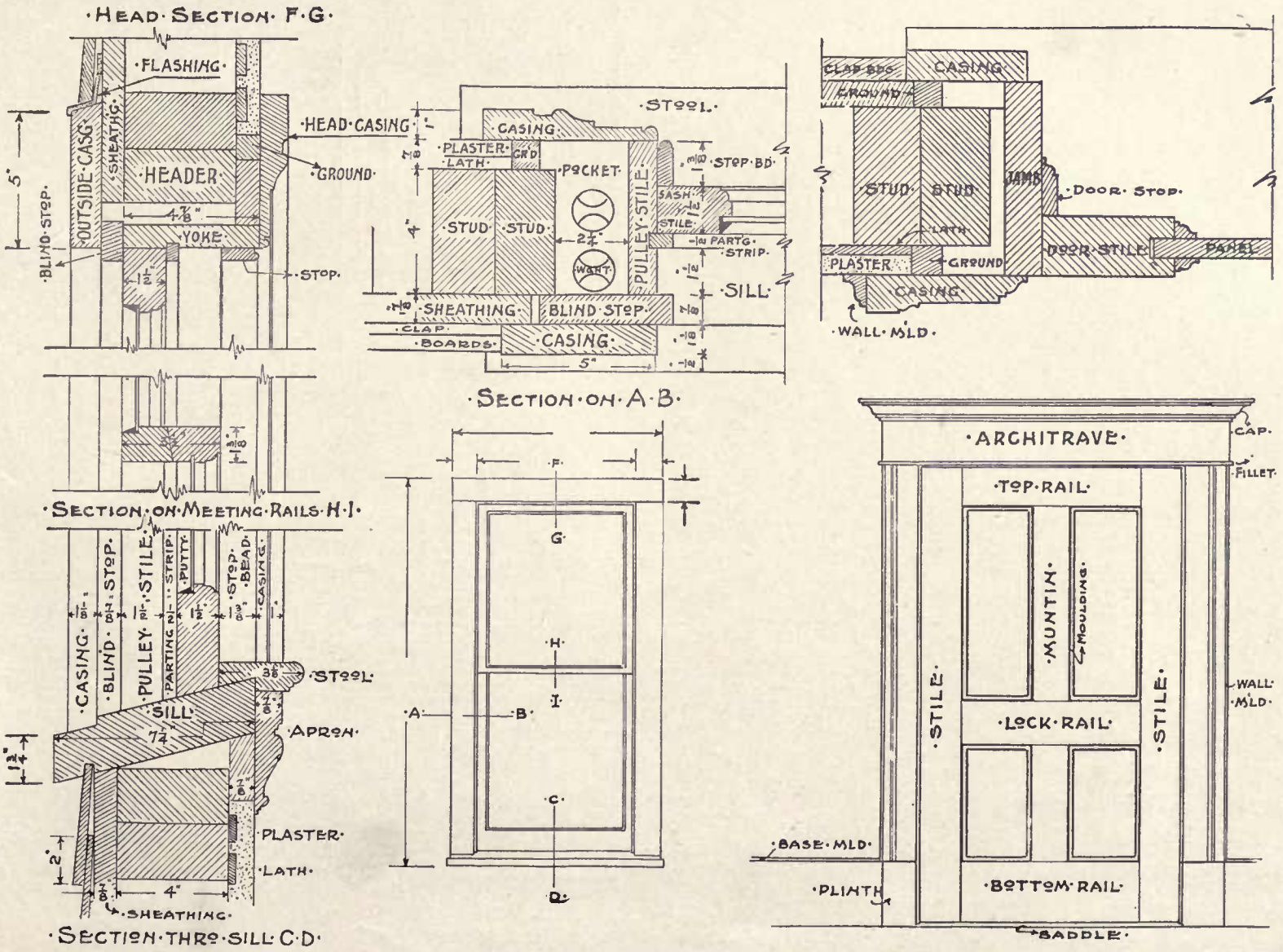
161. Working Drawings. The working drawing is made to scale and figured, unless the exact dimensions are not essential or are "stock" sizes. It should contain all the


SHINGLE LATH 7/8"×2"
RAFTER 2×8"
PLATE 4"×6"
LATH
PLASTER
FINISH FLOOR 3" WIDE
ROUGH FLOOR 7/8"×6"
BASE
FLOOR BEAM 2"×10"
RIBBAND PCE 1"×5"
LATH
PLASTER
GROUND FOR BASE
FINISH FL 3" WIDE
ROUGH FL 7/8"×6"
FLOOR BEAM 2"×10"
SILL 4"×6"
CELLAR WALL
STUD 2"×4"
BRICK FILL
FACIA
PLANCIER
PRIEZE 1¼"×8"
CLAPBOARDS
BUILDING PAPER
CLAPBOARDS
SHEATHING
WATER TABLE MLD
BED MLD
WATER TABLE
SHINGLE ROOF
GUTTER
CORNER BOARD



DETAILS OF WINDOW AND DOOR




HEAD SECTION F·G
FLASHING
OUTSIDE CASG
SHEATHG
HEADER
YOKE
BLIND STOP
STOP
HEAD CASING
GROUND
5'
4⅞"
1½"
STEEL
CASING
PLASTER
LATH
GRD
POCKET
STOP BD
STUD
STUD
2¼"
WGHT
PULLEY STILE
SASH
STILE
PARTG STRIP
SILL
4'
SHEATHING
BLIND STOP
CLAP
BOARDS
CASING
5"
SECTION ON A·B
F
G
H
I
A
B
C
D
CLAP BDS
CASING
GROUND
STUD
STUD
JAMB
DOOR STOP
LATH
PLASTER
GROUND
DOOR STILE
PANEL
CASING
WALL MLD
SECTION ON MEETING RAILS H·I
CASING
BLIND STOP
PULLEY STILE
PARTING STRIP
PUTTY
STOP BEAD
CASING
STEEL
SILL
APRON
7¼"
13¼"
PLASTER
LATH
2"
4"
SHEATHING
SECTION THRO SILL C·D
ARCHITRAVE
CAP
FILLET
TOP RAIL
MUNTIN
MOULDING
STILE
STILE
LOCK RAIL
BOTTOM RAIL
WALL MLD
BASE MLD
PLINTH
SADDLE

information required by the builder to properly lay out and proceed with the construction.

162. The working dimensions on a plan are the "stud measurements," that is, dimensions giving the locations of the stud lines for the exterior and interior frame; the size and location of doors, windows, chimneys, openings and other features. The locations of plumbing and lighting fixtures and radiators are also shown here, and such details of construction as do not require separate drawings are indicated.

163. The working dimensions on the elevations consist chiefly of the heights of the floors, or "beam measurements," that is, dimensions giving the locations of the floor beams or joists for the several floors with reference to the grade, curb, or sidewalk level. The distances of the window sills above the floor and the heights of the windows are also indicated.

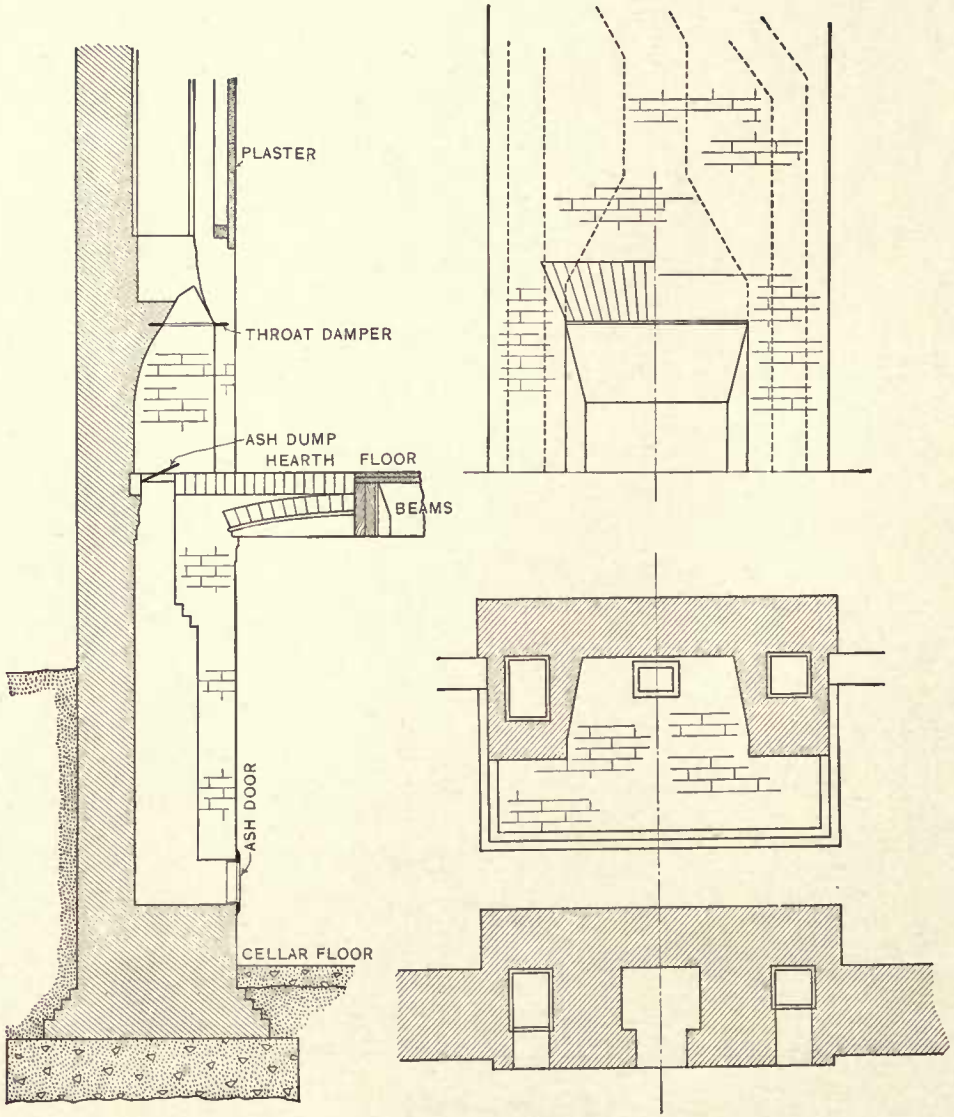


FIG. 118.—Chimney and Fire-place Construction.

The arrangement of the plumbing fixtures and sizes of the vent and drain pipes are sometimes shown on an elevation in dotted lines, but usually a *plumbing section* is shown.

164. Working drawings of details show the design and as

much construction as may be necessary, the latter, however, usually being left to the judgment of the builder. Details being drawn to a larger scale than the plans measurements may be found by "scaling," and all but the most important dimensions are, therefore, omitted. For this purpose details are often drawn to a scale of 1″=1 ft. The carpenter's ordinary "two-foot" rule has one edge with inches divided into twelfths for the purpose of scaling details. Other scales used for details are $\frac{3}{4}$″, 3″, and 12″.

165. In order to fully understand what has been said in the preceding paragraphs the pupil should make a careful study of Plates XXII to XXIX inclusive, which show a complete set of working plans, elevations, and details, of a suburban residence. Photographs of the completed structure are also shown and the pupil should compare these carefully with the drawings, line by line.

This will enable him to see how the builder's translation compares with the architect's composition, or, in other words the relation of expression in design to construction in material.

166. In many cases the use of standard materials and construction obviates the necessity of preparing complete working drawings, that is, the drawings are not figured, or the details are omitted altogether.

In addition to the drawings it is customary to furnish the builder with information in writing called specifications.

167. Specifications set forth the conditions of erection and payment, quality of labor and materials to be employed, kinds of materials, proportions of ingredients for concrete and plaster, and all other information which cannot be shown to advantage on the drawings. In fact the specifications not only supplement the drawings, but as far as practicable supplant them altogether. In many cases buildings have been erected from no other drawings than the floor plans, giving only the sizes of the rooms, and one or two elevations, the balance of the information being contained wholly in the specifications.

168. Common measurements in building construction are given below to assist the pupil in plan drawing:

Base,—$\frac{7}{8}$″×8″ or 10″.

Battens,—1″ to 1$\frac{1}{4}$″×2″ to 3″.

Chimney flues,—8″×8″, 8″×12″, 12″×12″; inside, allow 1″ extra each way for figuring chimney size.

Clapboards,—6″ wide, $\frac{1}{2}$″ thick at the butt, $\frac{1}{8}$″ thick at other end and 4′–0″ long. They should not exceed 6″ in width, for otherwise they are likely to warp.

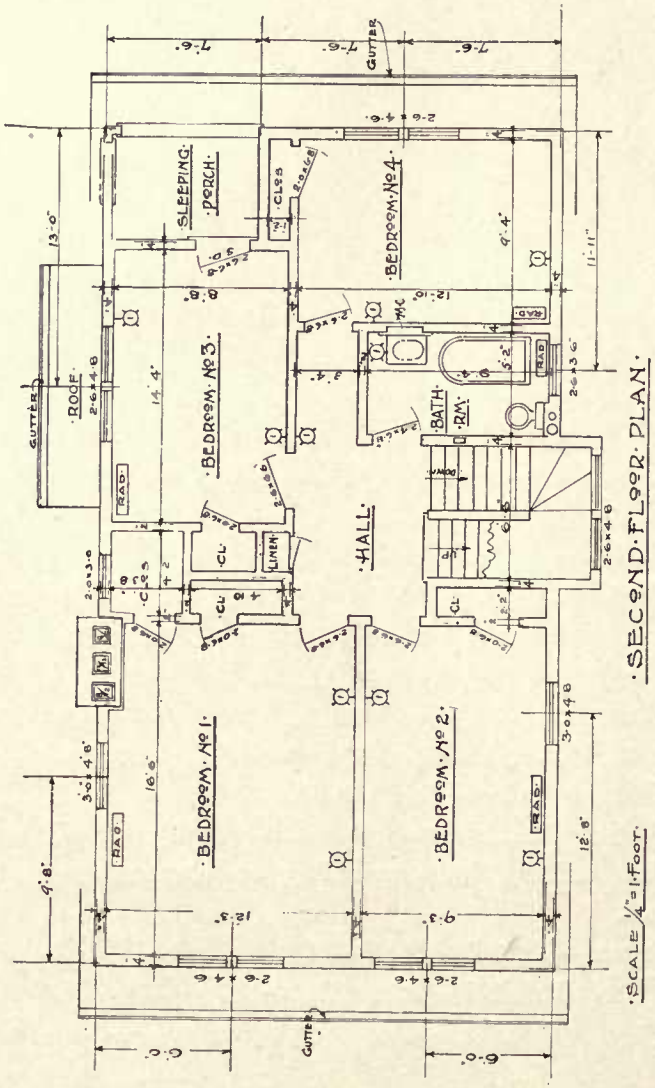
Corner boards,—$\frac{7}{8}$″×4″ to 6″.

Corner boards are put on vertically at all angles of the building for the siding or clapboards to butt against.

Doors,—closet 2′–6″×6′–6″.

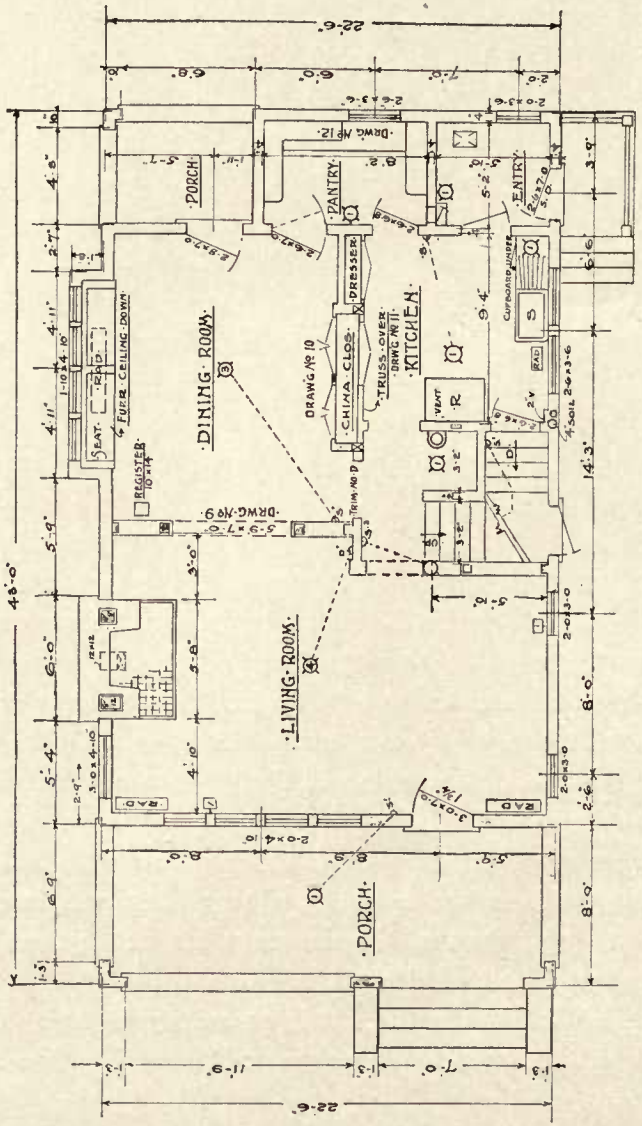
Inside 2′–8″×6′–8″, 2′–10″×6′–10″.

Outside 3′×7′.



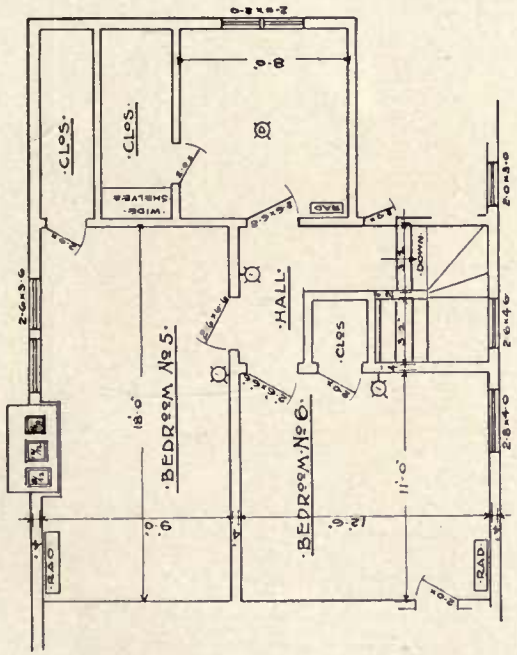
SECOND FLOOR PLAN.

SCALE 1/4" = 1 FOOT.



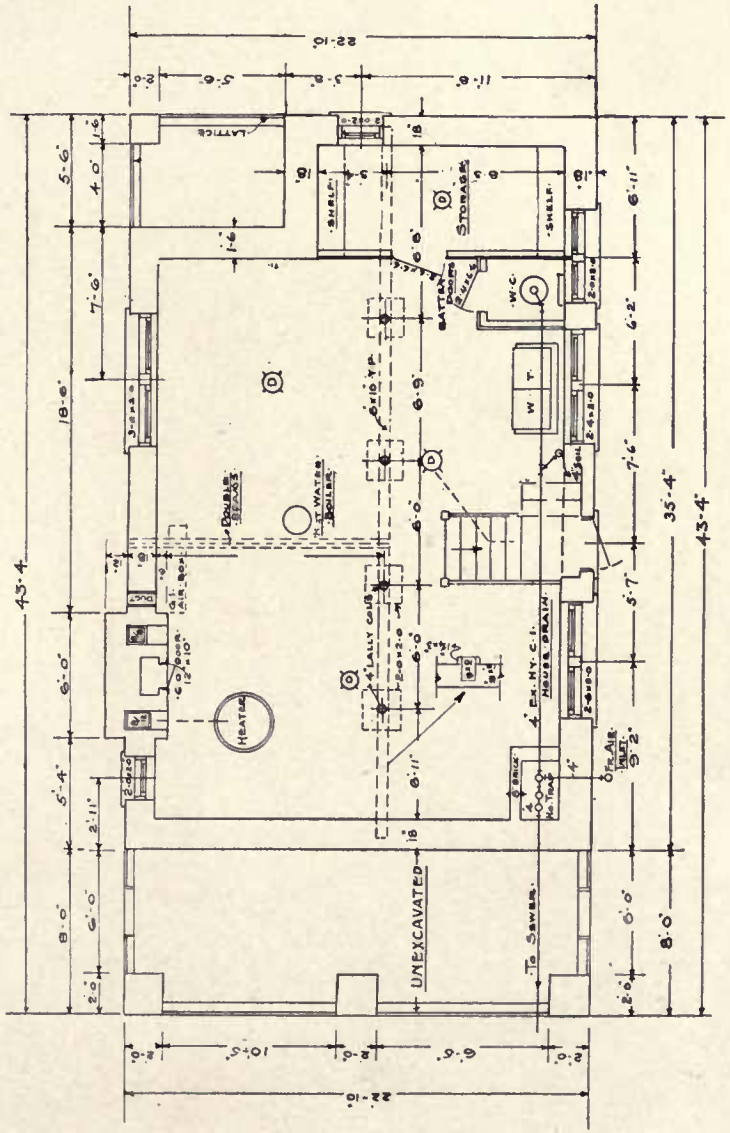
FIRST FLOOR PLAN.

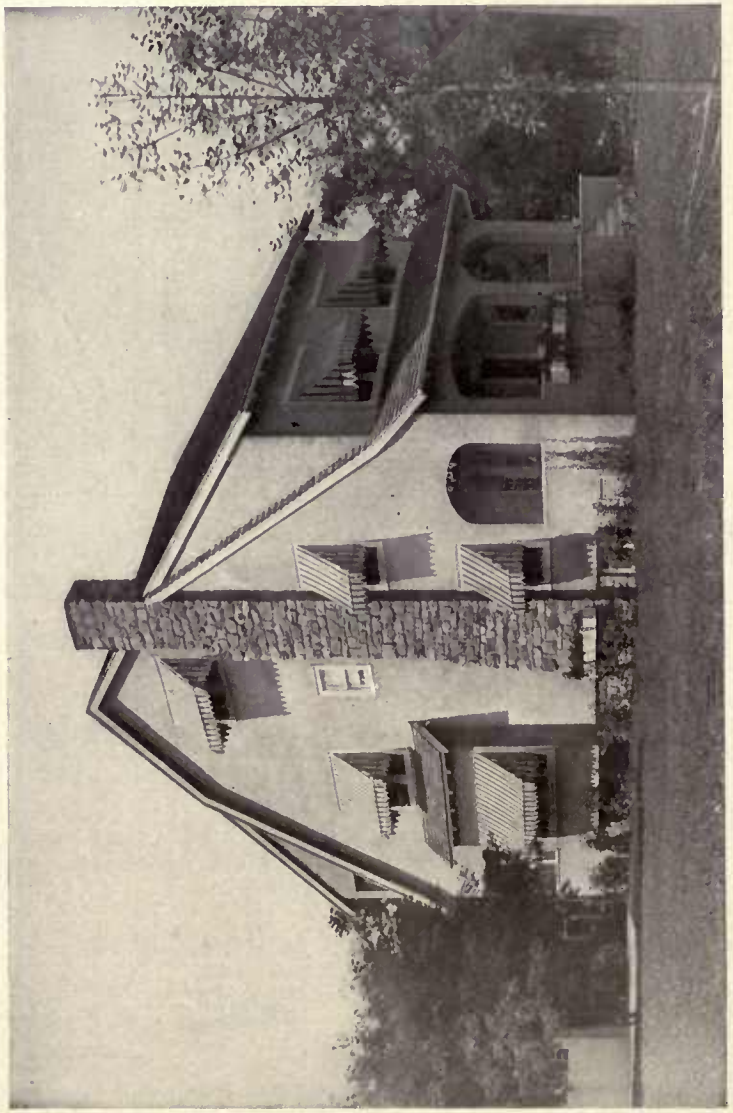
SCALE 1/4" = 1 FOOT.



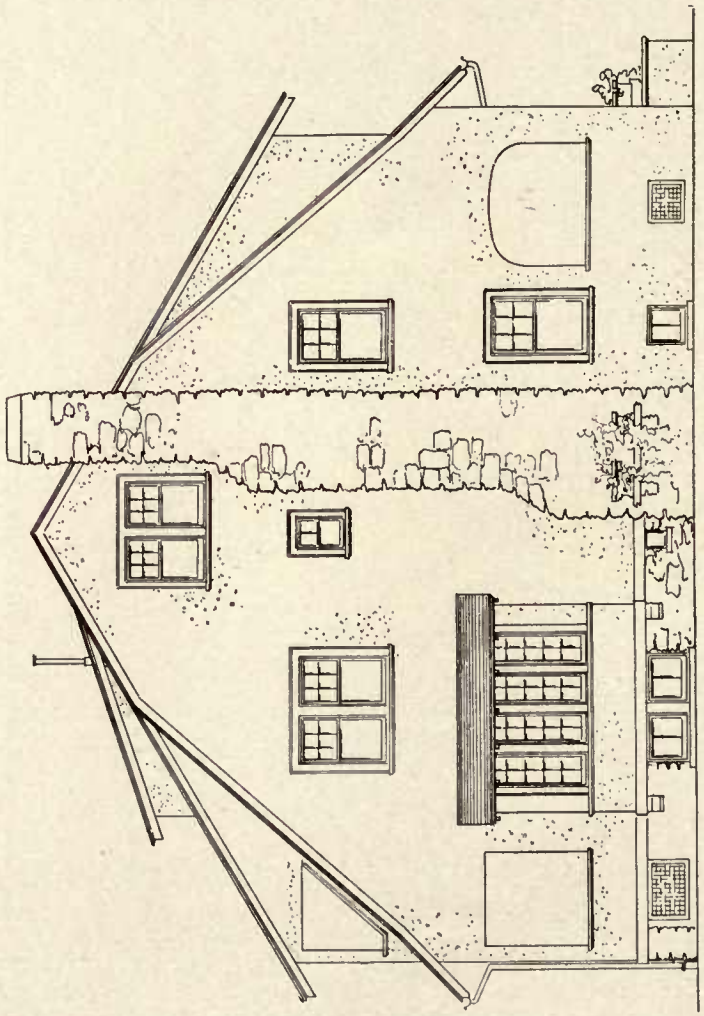
ATTIC FLOOR PLAN.

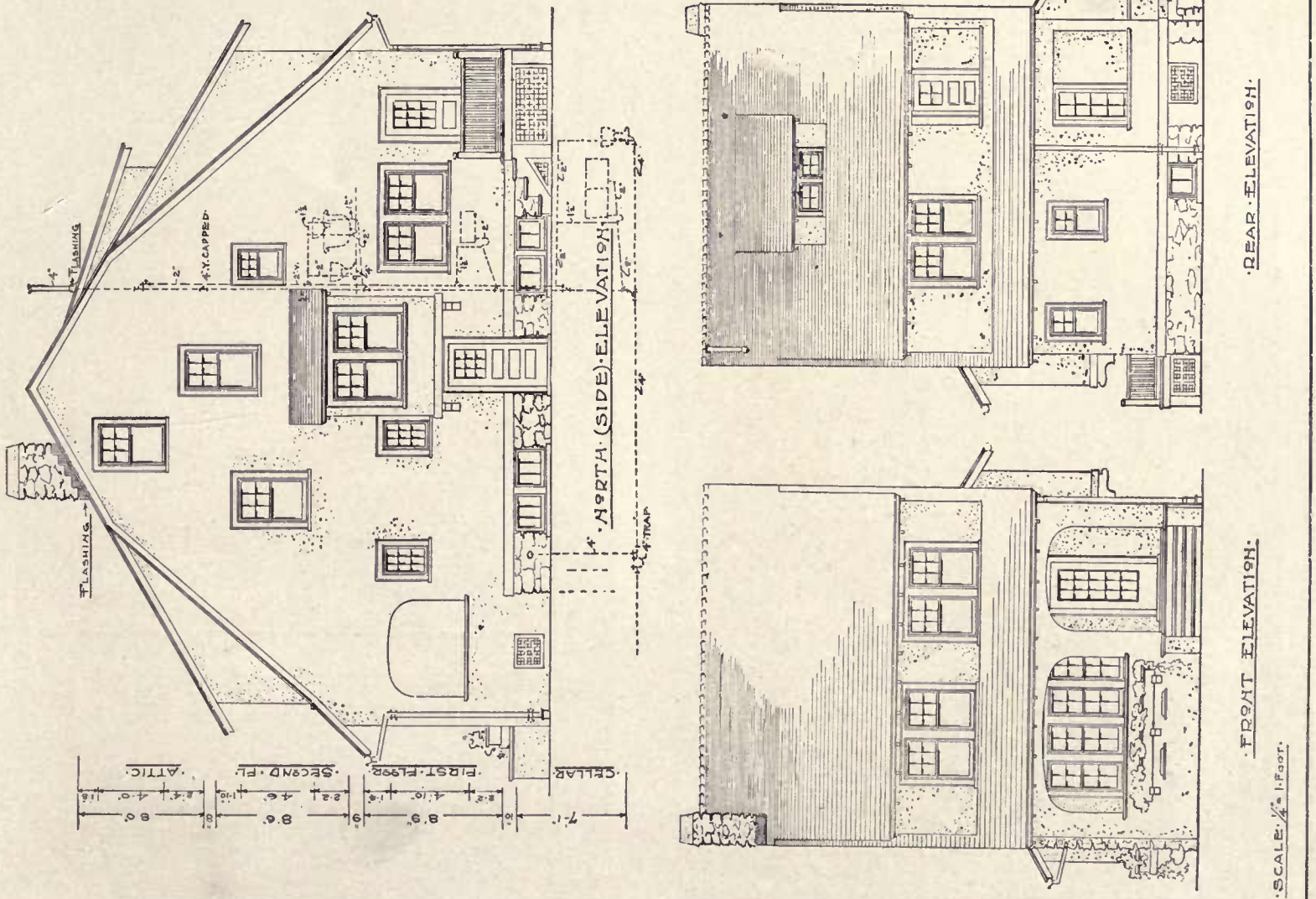
SCALE ¼" = 1 FOOT.

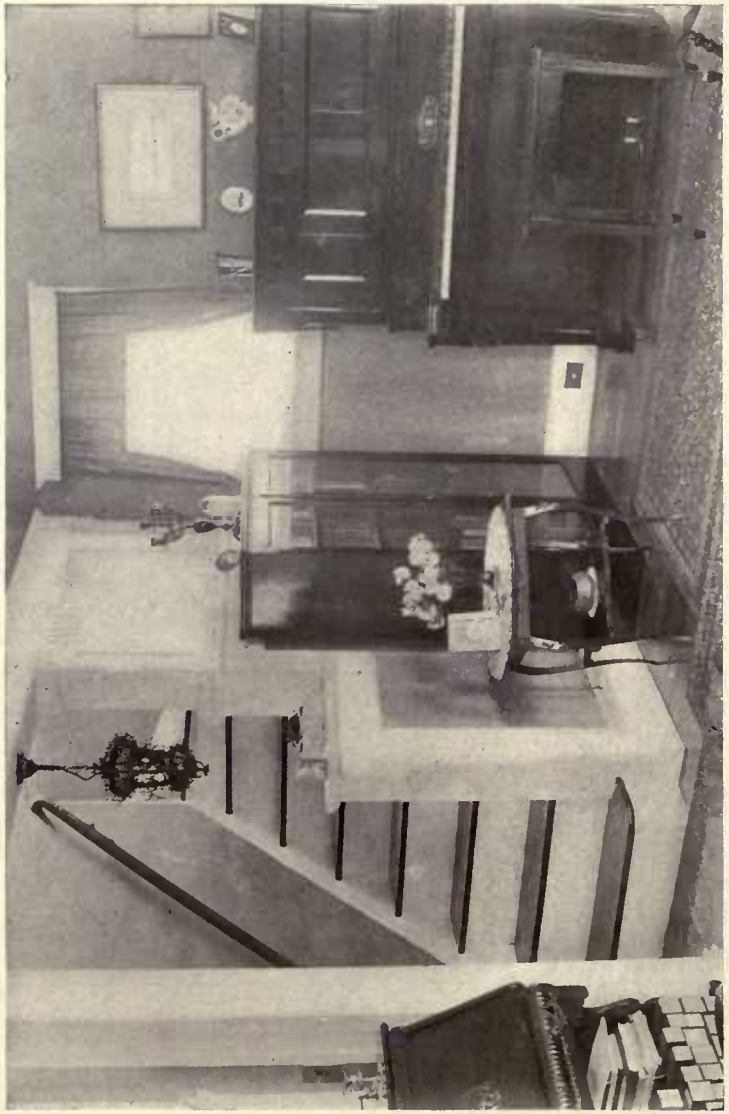

LATTICE
SHELF
STORAGE
SHELF
W.C.
BATTEN DOOR
BRICK
W.T.
DOUBLE FLEAKS
HOT WATER BOILER
CAT IRON
4" BRICK
4" CONC.
4" BRICK
4" CONC.
4" BRICK
4" CONC.



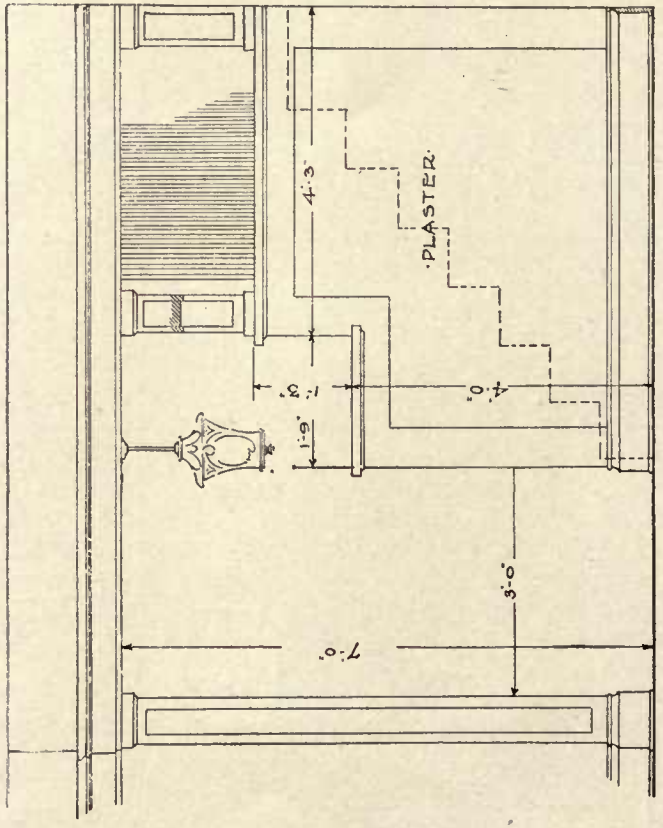
NOTE: Compare this photograph of the actual building with the drawing below.



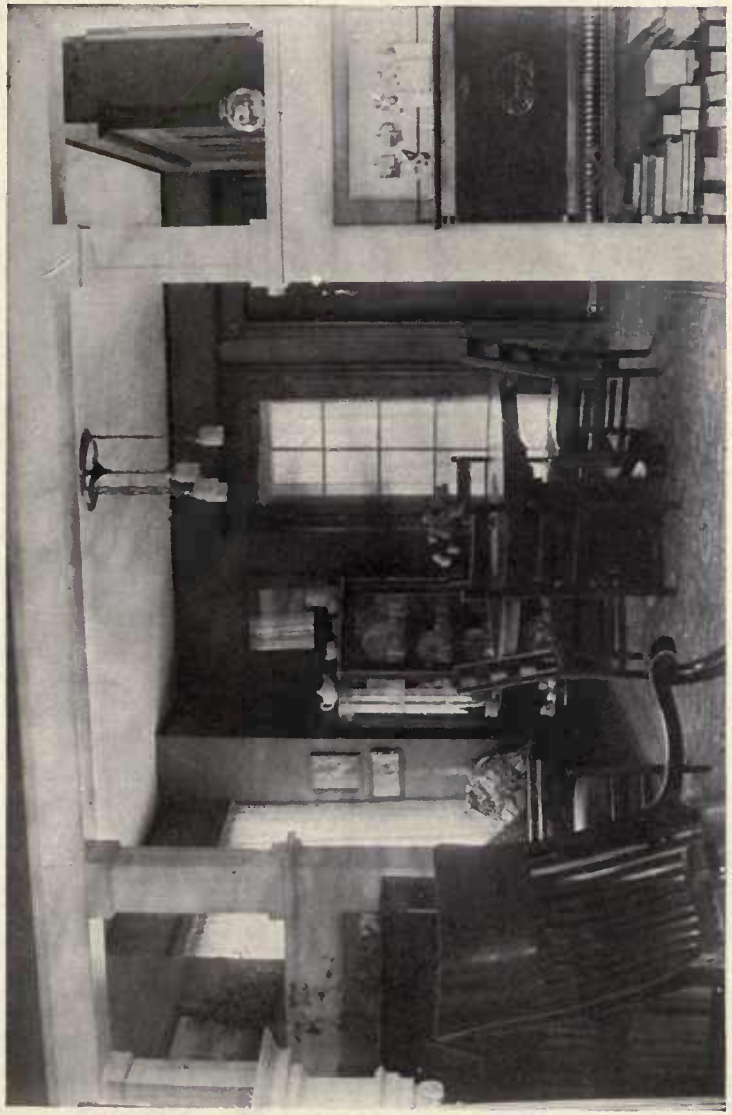

NORTH (SIDE) ELEVATION
REAR ELEVATION
FRONT ELEVATION
SCALE: ¼" = 1 Foot
FLASHING
4" FLASHING
4" V. CAPPED
4" TRAP
ATTIC
SECOND FL.
FIRST FLOOR
CELLAR
8'0"
8'6"
8'9"
7'1"



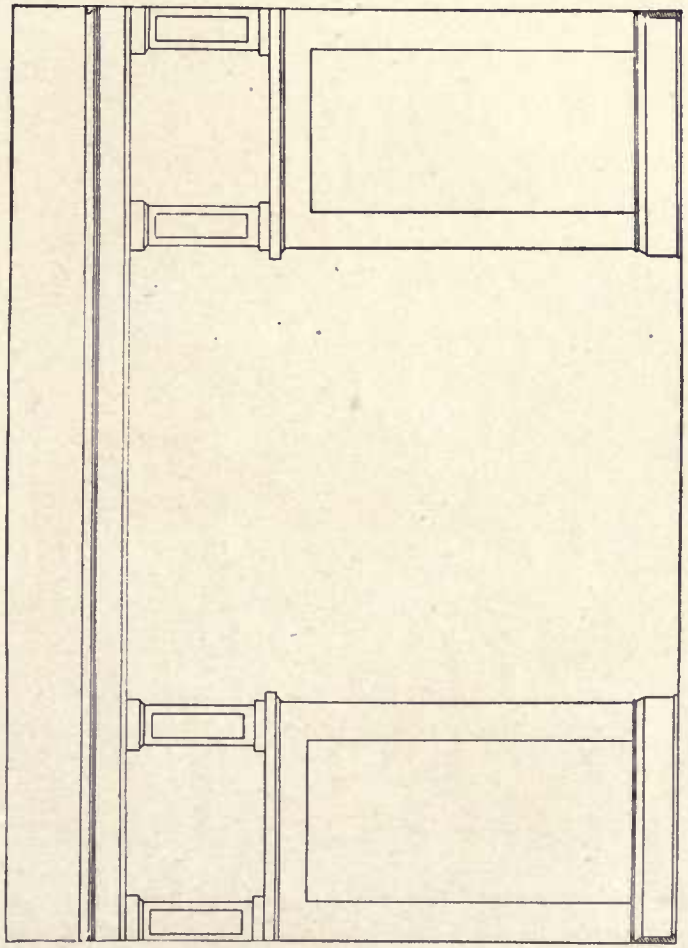
NOTE: This is a photograph of the detail built from the drawing shown below

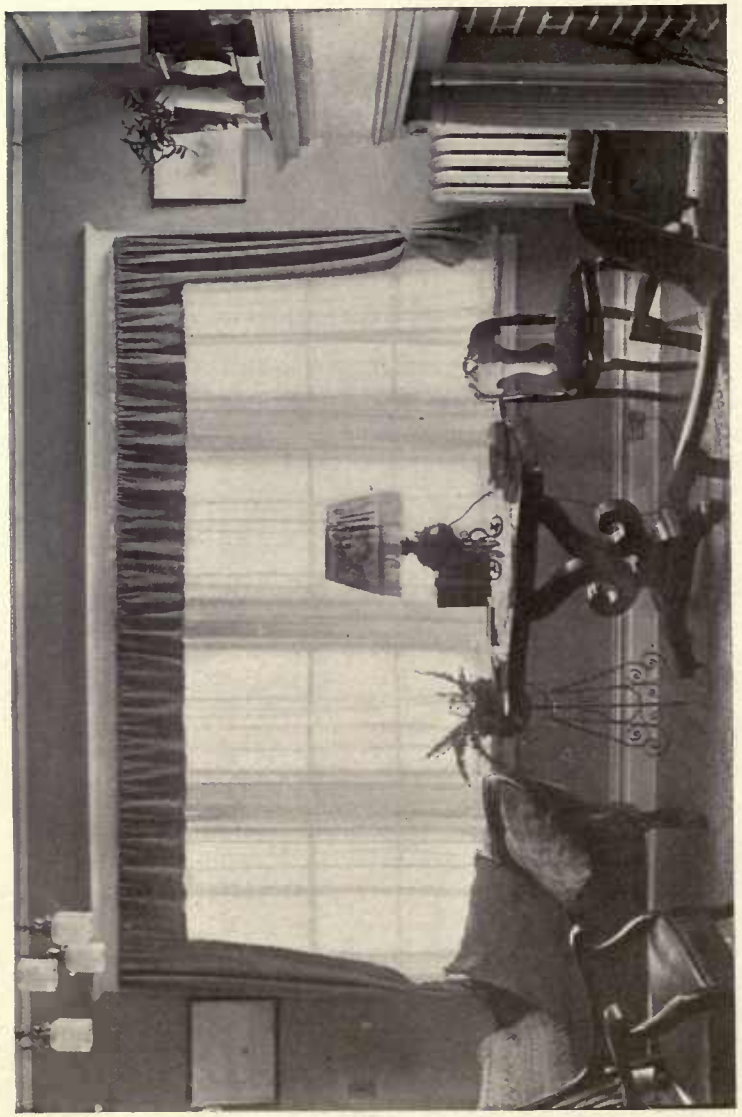


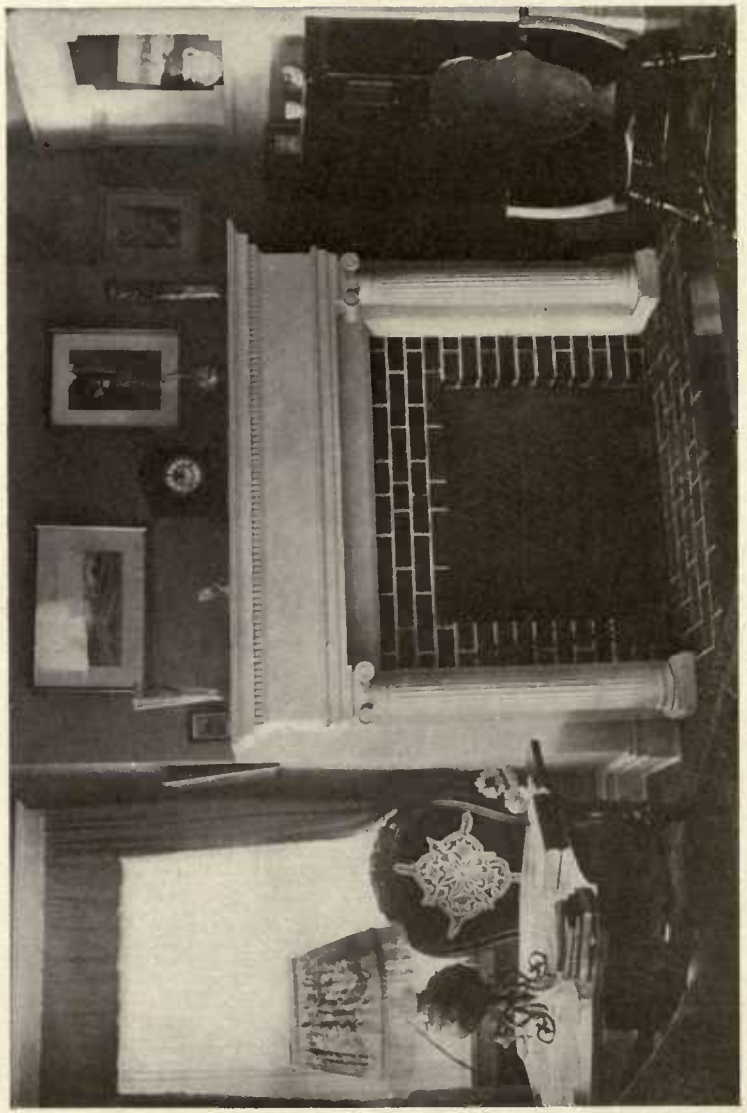
SCALE 1"=1 FOOT. DRAWING Nº 8.

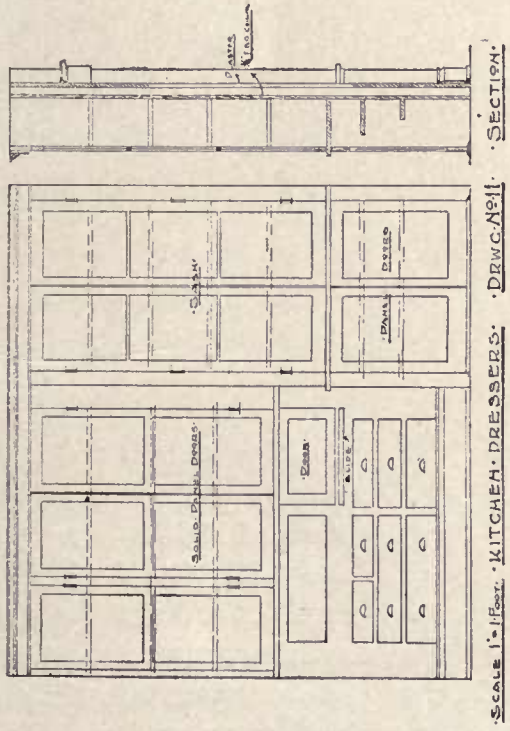


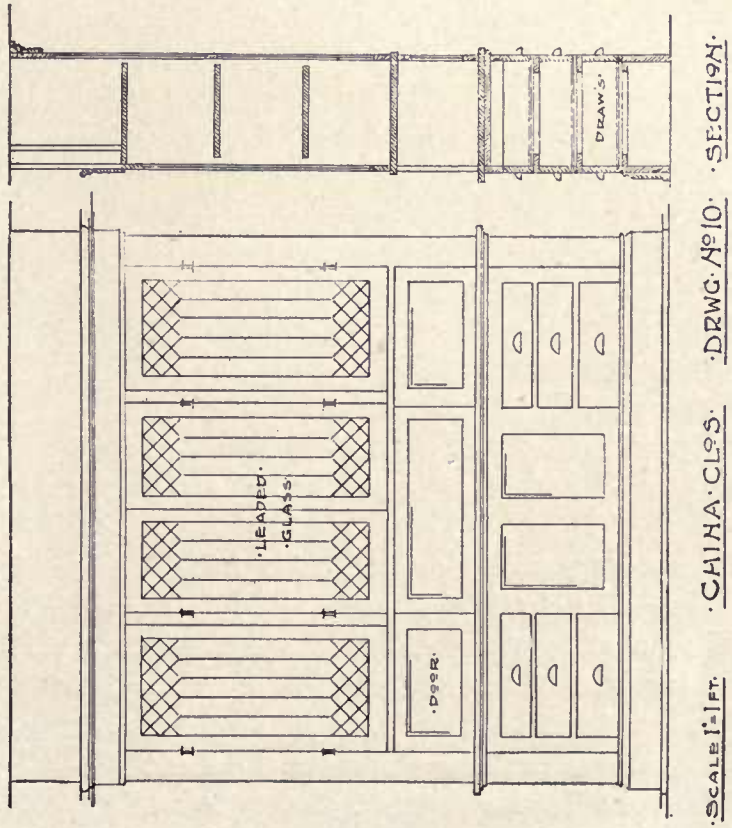
NOTE: This is a photograph of the detail built from the drawing shown below.








SCALE 1"=1 Foot. KITCHEN DRESSERS. DRWG. No 11. SECTION.


SCALE 1"=1 FT. CHINA CLOS. DRWG. No 10. SECTION.
LEADED GLASS
DOOR
DRAWS

Floors,—Under $\frac{7}{8}''\times 6''$.
Finish $\frac{3}{8}''$ to $\frac{7}{8}''\times 1\frac{1}{4}''$ to $3\frac{1}{2}''$.
Height from grade $3\frac{1}{2}'$.

Furring strips,—$\frac{3}{8}''$ to $\frac{7}{8}''\times 2''$.

Girders,—6″ or 8″×8″ to 12″.

Grounds,—$2''\times\frac{5}{8}''$ for two coats of plaster.
$2''\times\frac{3}{4}''$ for three coats of plaster.

Headers and trimmers,—4″×depth of beam.

Height of ceilings,—9′ first floor, 8′ second floor.

Joists,—2″×8″ to 12″, 16″ o.c. (on centers).

Laths,—$\frac{3}{8}''\times 1\frac{1}{2}''\times 4'$; $\frac{1}{4}''$ apart, break every tenth lath.

Plaster,—$\frac{3}{4}''$—two coats, $\frac{7}{8}''$—three coats.

Plate,—4″×4″ or 4″×6″.

Posts,—4″×4″, 4″×6″, 4″×8″.

Rafters,—2″×6″ to 12″; 18″ or 20″ c.c. (center to center).

Shingles,—exposed $4\frac{1}{2}''$ on roof, 5″ on wall.

Siding,—6″ wide; $\frac{1}{2}''$ thick tapering to $\frac{1}{4}''$; exposed 5″.

Siding should not exceed 6″ in width. It is about $\frac{1}{8}''$ thicker than the dimensions stated for clapboards, and comes in lengths of from 10 to 16 ft. Rebated siding gives a tight joint and insures accurate alignment.

Sill,—4″×6″, 6″×6″, 6″×8″.

Studs,—2″×4″, 16″ o.c.

Stairs,—rise 7″ to $7\frac{1}{2}''$; tread 9″ to 10″.

Walls,—6″ thick, inside; 7″ outside.

Windows,—5′×2′–6″; height from floor 2′.

169. It is customary to "double the studs,"—that is, place two together, around door and window openings. There are two methods for laying out the studding, as follows:

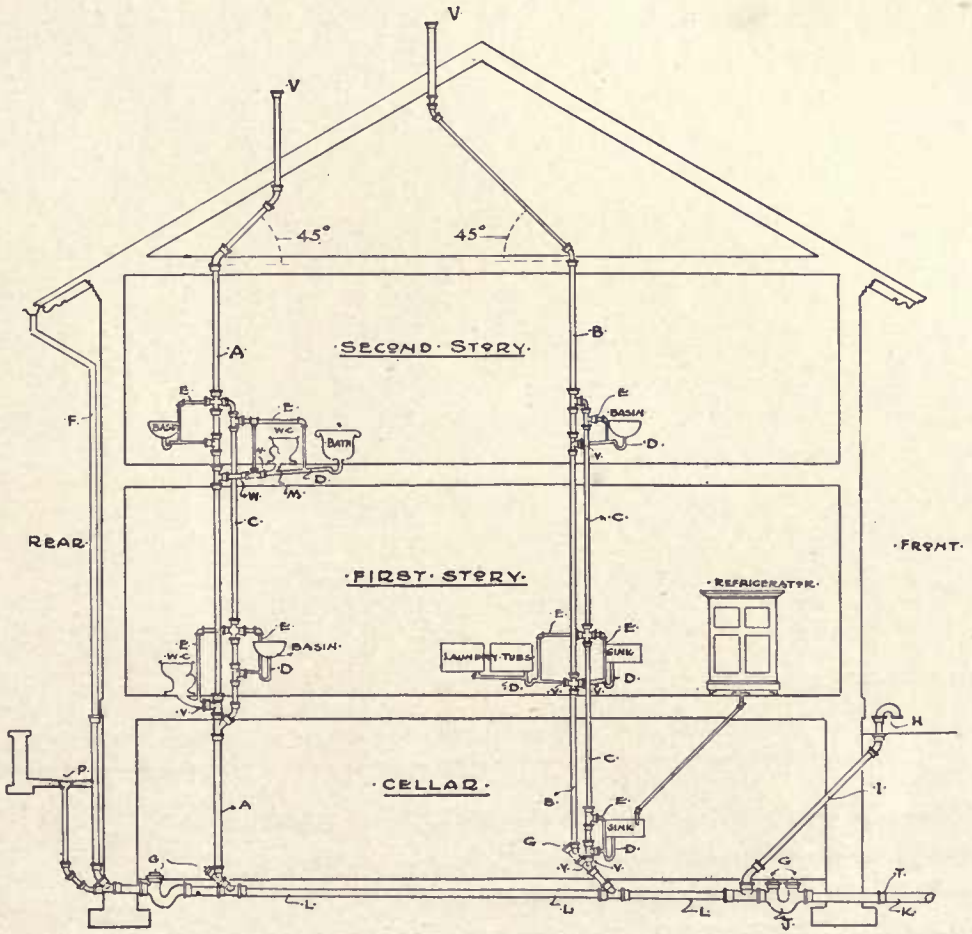
First Method. Double the studs at the sides of doors and windows first, then space the studs 16″ on centers.

Second Method. The studs are spaced uniformly 16″ on centers, after which the door and window openings are sawed out and the studs are framed.

170. Plumbing and Sanitation. In the erection of a building of any considerable size, drawings are required for the installation of the plumbing, heating, ventilating, and lighting. For a smaller building these can be comprehended in the specifications, the locations only of fixtures, outlets, etc., being shown on the drawings. The relative locations of sanitary fixtures is an important matter as affecting the cost of installation. Fixtures on the same floor should be adjacent, if possible, and those on the upper floors should be arranged directly over those below, that the same risers, vents, and drains may be utilized. This will be clearly understood by referring to the "plumbing section" shown on Plate XXX.

171. Materials of Construction. Buildings are constructed of wood, brick, stone, hollow tile, concrete, and metal. These materials are used singly or in combination, except that wood is used nearly always to a greater or less

·A· Soil Line
·B· Main Waste
·C· Main Vent
·D· Branch Waste Pipes
·E· Branch Vent
·F· Rain Water Leaders
·G· Removable Screw-Caps
·H· Cap
·I· Fresh Air Inlet
·J· House Trap
·K· House Sewer
·L· House-Drain
·M· Branch Soil Pipe
·N· Screw-Cap
·P· Area Drains
·T· Mouth of House Drain
·V· Water Seal
·W· Branch Soil Pipe



extent. The selection of materials will depend largely upon their first cost and other local conditions. The present tendency is toward the use of the more substantial and permanent kinds of materials, especially hollow tile and concrete. The first cost of these materials is usually

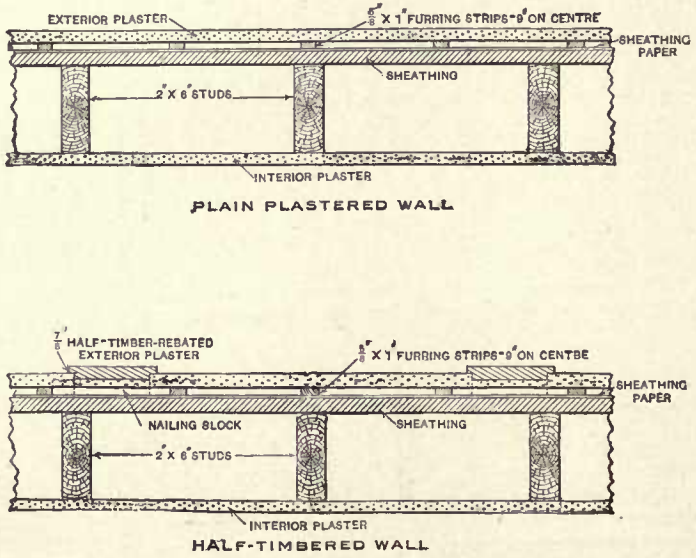


FIG. 119.—Detail of Construction for Stucco Finish.

in excess of that for timber, but if the items of repair, painting, and durability are taken into account, the balance will be likely to fall on the other side.

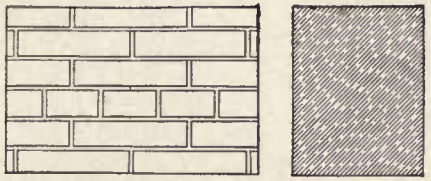
With the increasing cost of timber on the one hand, and the improving and perfecting of the methods of manufacturing and handling tile and concrete on the other, it is probable that even the discrepancy in first cost will soon disappear.

172. The many advantages of tile and concrete over other forms of construction are apparent; their durability and

FIG. 120.—Showing Effect in Stucco Finish—Timber, Tile, or Concrete may be used.

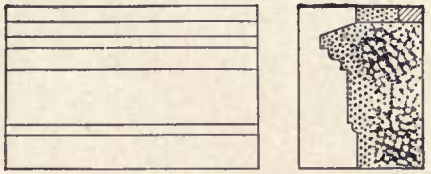
fireproof quality are virtues of exceedingly great value. Buildings in the country lend themselves with peculiar fitness to this form of construction, as their situation makes their permanence possible, and, in the lack of

BRICK



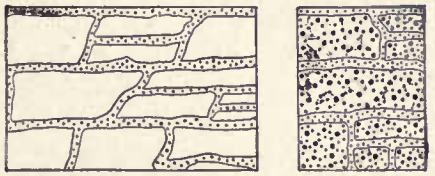
ELEVATION SECTION

STONE



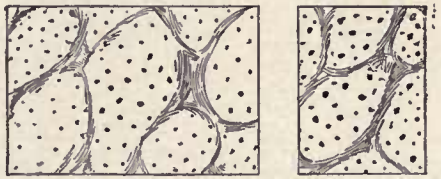
ELEVATION SECTION

RUBBLE



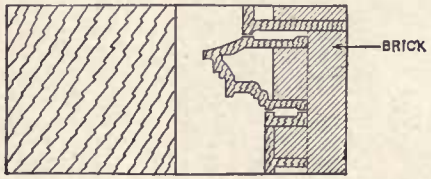
ELEVATION SECTION

MARBLE



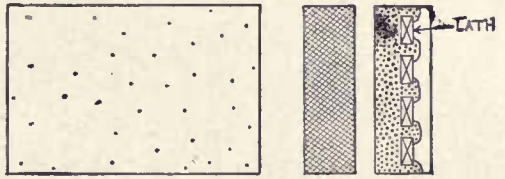
ELEVATION SECTION

TERRA COTTA



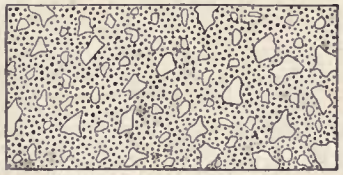
SECTIONS

PLASTER



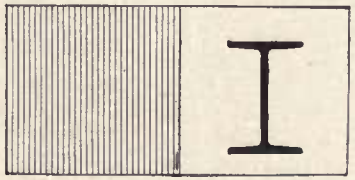
ELEVATION SECTIONS

CONCRETE



ELEVATION & SECTION

METAL

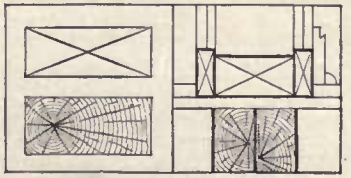


ELEVATION SECTION

EARTH

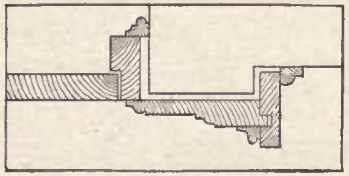
SECTION

ROUGH LUMBER



SECTIONS

FINISHED LUMBER



SECTION

other protection, necessitates that the materials used should be of fire-resisting properties.

173. The conventional representation of materials is shown on Plate XXXI. There is no fixed standard for these and

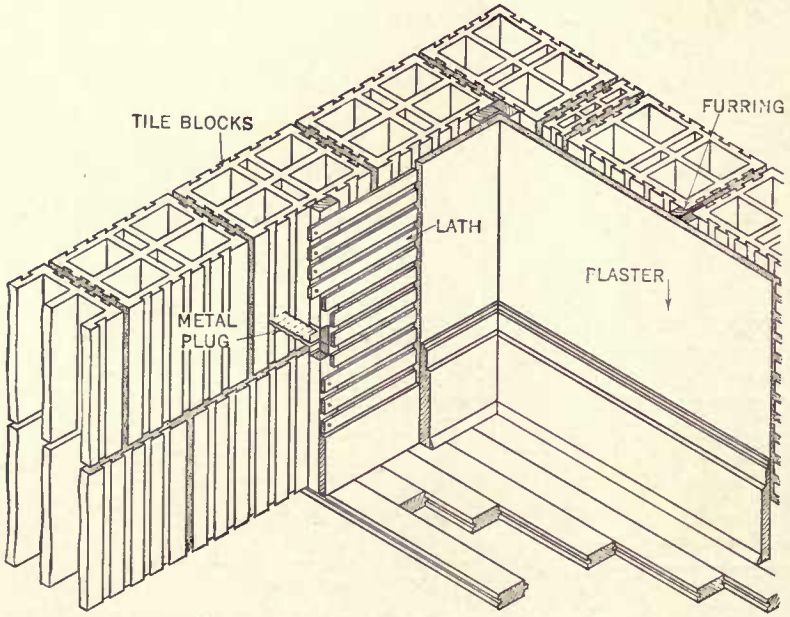


FIG. 121.—Detail of Wall Construction in Hollow Tile.

frequently the draftsman places on the drawing a "key" to the conventions used.

174. Stucco is the name given to a method of finishing exterior walls. In place of the siding or shingles two or three coats of specially prepared plaster are spread over metal lath nailed to furring strips as indicated in Fig. 119. This style of finish when properly applied is very durable, saves expense of painting, and is fire resisting. It also possesses a great value as a medium for artistic treatment and has therefore become deservedly popular. The residence shown on Plates XXII to XXIX is finished in stucco.

The possibilities of home building in stucco, tile, or concrete construction are exemplified in Fig. 120. Note how simple charm and elegance are secured by the omission of all ornate and superfluous details.

175. The general features in the **details of construction in tile and concrete** are very similar. In Fig. 121 is shown a detail of wall construction with the use of tile.

A building of the construction detailed in Fig. 121 cannot be characterized as fireproof, except as to its walls. The walls, of

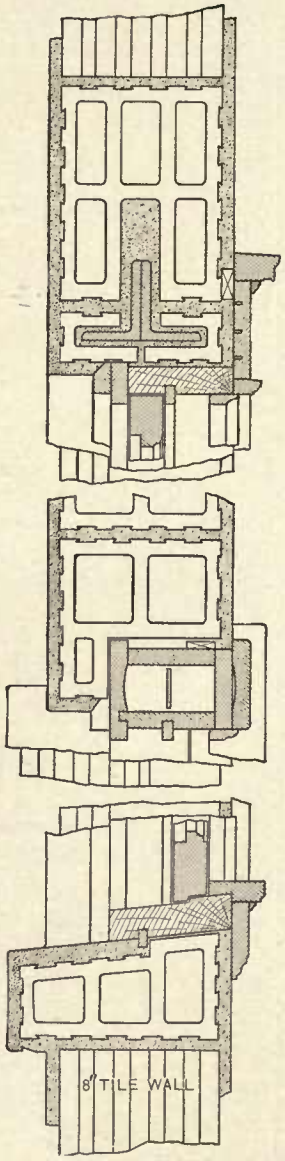


FIG. 122.—Detail of Window-sill, Jamb and Lintel in Hollow Tile.

course, give the superior insulating value of tile construction, insuring a warm, dry interior in winter and a cool house in summer. They also permit the plastering to

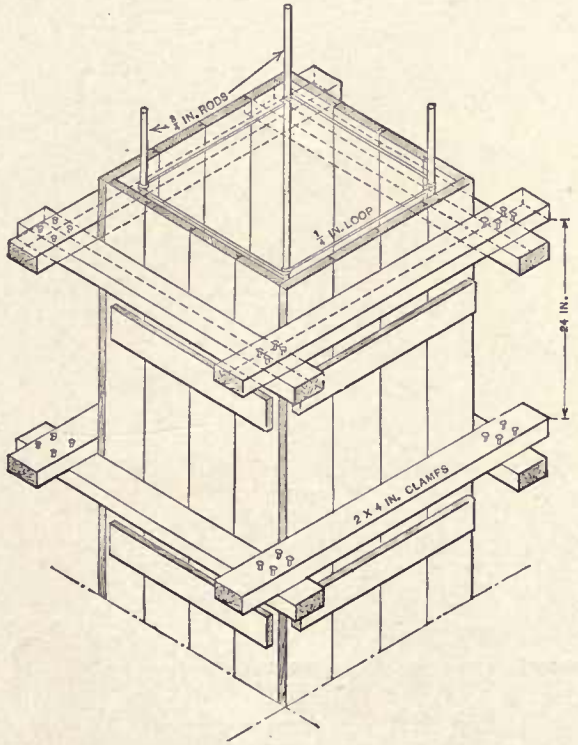


Fig. 123.—A Simple Form for a Column.

be applied directly to the tile wall without the use of furring or lathing, thus effecting a further economy, except perhaps in the case of the inside of the exterior wall as shown.

176. Details of wall sections are shown on Plate XXXII. Note the method of anchoring the roof plate to the tile, also the method of carrying the wooden joists on the roof plate and of bolting them to the roof timbers.

In Fig. 122 are shown details of a window-sill, jamb, and lintel.

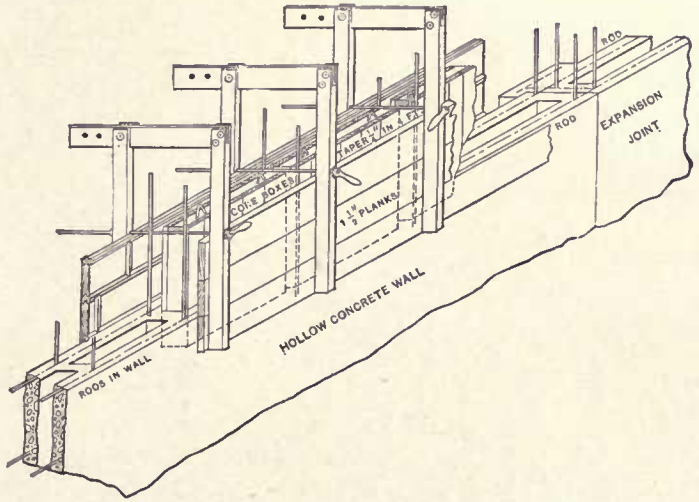
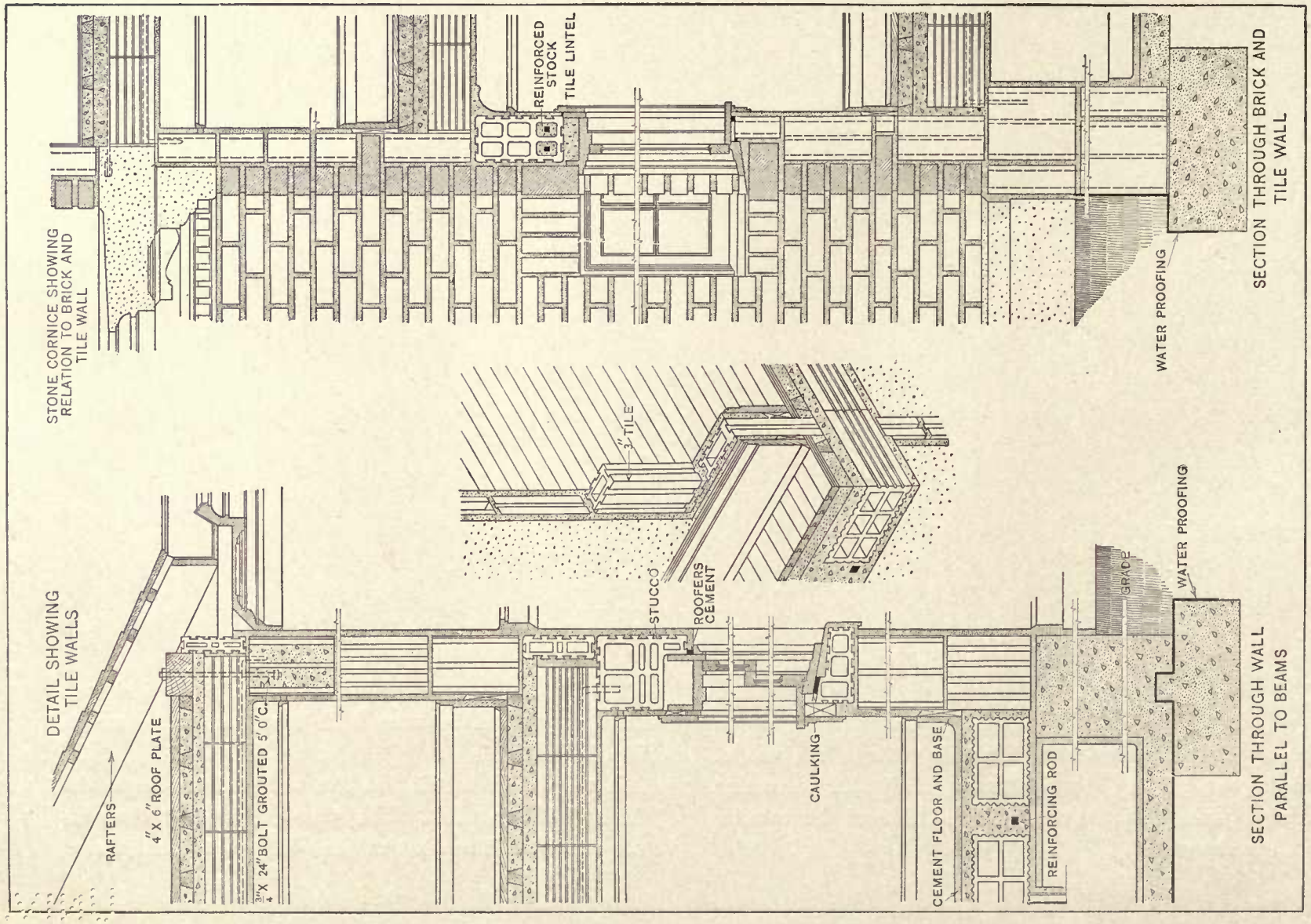
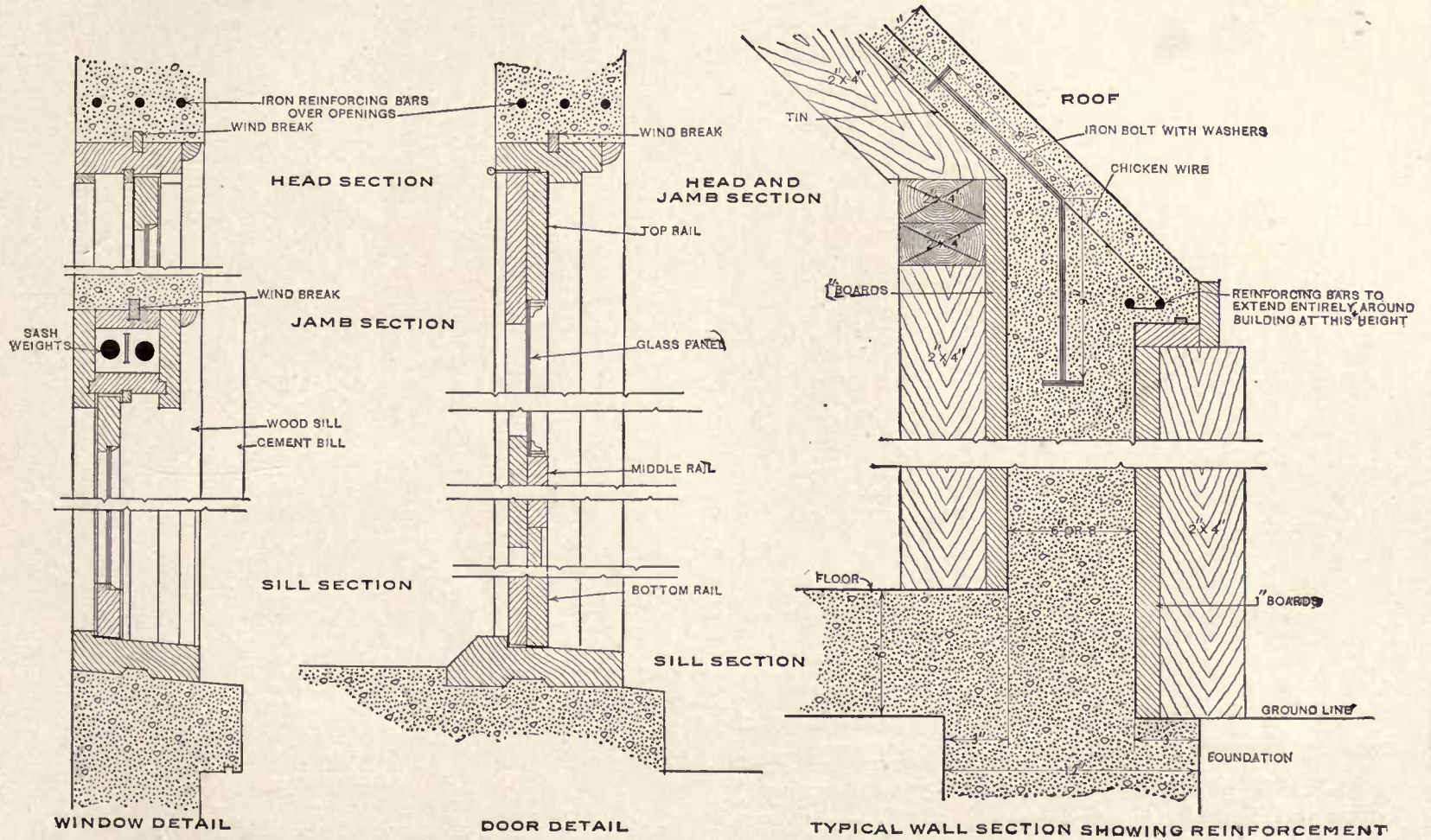


Fig. 124.—Hollow Wall Forms.

177. Details of doors and windows, and a typical wall section as applied to monolithic concrete, are shown on Plate XXXIII.

It will be observed that the wall section shows the "forms" still in place. The space occupied by the concrete corresponds to that of the tile in the detail shown


STONE CORNICE SHOWING RELATION TO BRICK AND TILE WALL
REINFORCED STOCK TILE LINTEL
WATER PROOFING
SECTION THROUGH BRICK AND TILE WALL
3" TILE
STUCCO
ROOFERS CEMENT
DETAIL SHOWING TILE WALLS
RAFTERS
4" X 6" ROOF PLATE
3/4" X 24" BOLT GROUTED 5' 0" C.
CAULKING
CEMENT FLOOR AND BASE
REINFORCING ROD
GRADE
WATER PROOFING
SECTION THROUGH WALL PARALLEL TO BEAMS


IRON REINFORCING BARS OVER OPENINGS
WIND BREAK
HEAD SECTION
WIND BREAK
JAMB SECTION
SASH WEIGHTS
WOOD SILL
CEMENT BILL
SILL SECTION
WINDOW DETAIL
WIND BREAK
HEAD AND JAMB SECTION
TOP RAIL
GLASS PANEL
MIDDLE RAIL
BOTTOM RAIL
SILL SECTION
DOOR DETAIL
ROOF
TIN
IRON BOLT WITH WASHERS
CHICKEN WIRE
2" x 4"
1" BOARDS
REINFORCING BARS TO EXTEND ENTIRELY AROUND BUILDING AT THIS HEIGHT
2" x 4"
6" OR 8"
2" x 4"
FLOOR
1" BOARDS
GROUND LINE
FOUNDATION
TYPICAL WALL SECTION SHOWING REINFORCEMENT

above. It is advisable, however, in using this form of construction for a dwelling house, to "fur out" on the inside, thus creating a space between the outer wall and plaster and preventing the condensation of moisture on the latter with its serious consequences. The outside wall

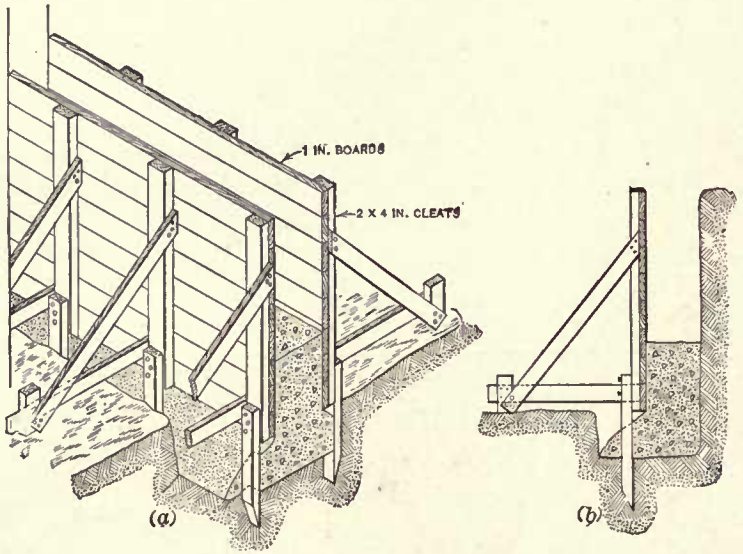


FIG. 125.—Cellar Wall Forms.

is sometimes waterproofed to prevent the penetration of moisture through the wall from the outside. This may also be prevented, wholly or in part, by constructing a hollow wall, but this is more expensive. For most buildings except the dwelling house, a monolithic wall, with nothing else, will answer all purposes.

178. When concrete is "cast," or "poured," a **mold** or **form** is required to give it shape and hold it until it

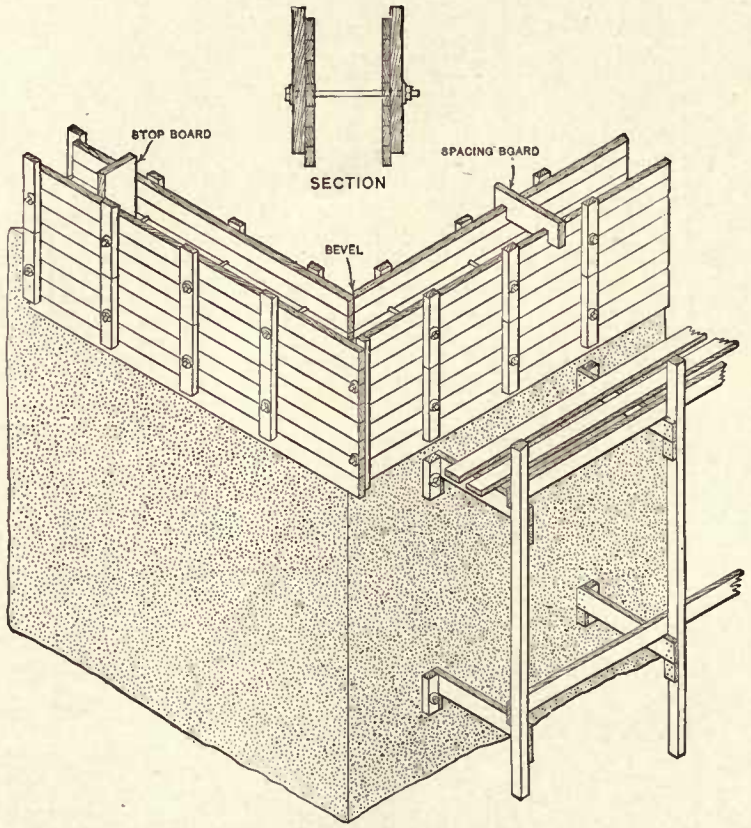


FIG. 126.—Wall Forms.

hardens or sets. A simple form is shown in Fig. 123. Fig. 124 illustrates the type of construction which requires an inside form, as well as an outside. In Fig. 125 is shown

a simple design for cellar or foundation walls. Note that the forms are lifted to allow the concrete to flow out and form a *spread footing*.

Fig. 126 shows a design of wall forms for building a solid wall of any height. The form sections are each made 2 feet high and the length depends upon the length of boards at hand. A 2-foot section made of 1-inch boards 10 feet long weighs 55 pounds. Such a form can therefore be handled easily by one man. The cleats are made to lap over the top of the form $1\frac{1}{2}$ to 2 inches, in order to catch the next section placed on top of the one just filled with concrete. Notice, also, that the cleat at one end projects beyond the form bracing so as to catch the next section and hold it in place. Bolts for holding the forms together are better than wires, which cut into the cleats and spring the forms apart.

Circular forms are required for cylindrical constructions, such as a cistern, cess-pool, or tank.

179. In drawing plans the student must begin with a very simple problem. His first aim should be to learn the methods and conventions employed and how to express them in the characteristic lines of this class of drafting.

The student is advised to avoid very much expression of individuality on the aesthetic side until the "sense" has been cultivated and good taste acquired. It is better to conform strictly to a proved practice at first and gradually develop individuality. To the observing student it will soon be apparent that good taste and refinement are best expressed through simplicity, proportion, and harmony rather than by means of embellishment or striking details.

CHAPTER VIII

PLOT AND MAP DRAWING

180. Topographical drawing is the representation on paper of a limited area or tract of land, including the boundaries, divisions, roads, buildings, and such natural features as streams, lakes, swamps, and trees. It is also made to include the form of the surface, showing the depressions and elevations.

181. The instruments and materials used in topographical drawing are substantially the same as for other kinds. The scales, however, are graduated differently; the inch is divided into 10, 20, 30, 40, 50, 60, 80 and 100 parts. Drawings are often made to a scale of 200 feet or more to the inch, and in such cases, the standard graduation is used and multiplied mentally by ten or other convenient factor. Cross-section paper having ten divisions to the inch is frequently used in this work.

182. A topographical map is made from data which are usually obtained from a survey that includes: (*a*) the length and directions of the boundaries; (*b*) elevations and depressions; and (*c*) a description of the natural and artificial features.

Plotting is the delineation or representation of a survey.

183. The direction of the magnetic needle is known as the **magnetic meridian** and the acute angle that a line makes with it is called its *magnetic bearing*. See Fig. 127. Such angles are designated thus: N. 30° E., and are read *north thirty degrees east;* which means that the line bears to the east 30° from the magnetic meridian.

The bearing and length of a line are called its **course**. Sometimes one side of a plot is chosen as an arbitrary reference line without regard to either the magnetic or true meridian.

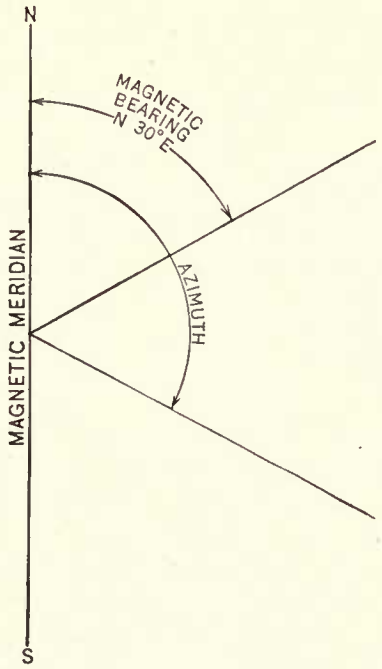


FIG. 127.

Bearings computed thus are known as *false bearings.*

184. The total angle which a course makes with the meridian is called the **azimuth.** This angle may be acute or obtuse and may be read from the north or south,

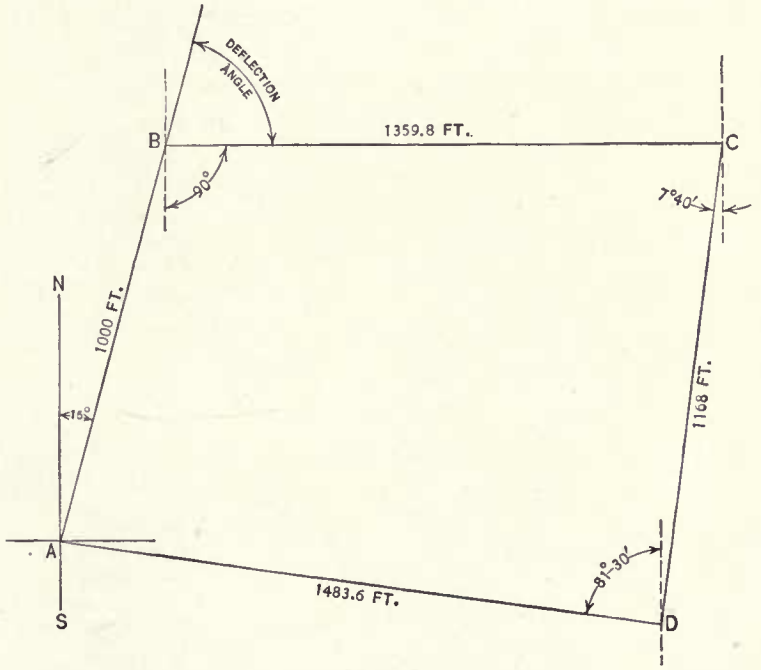


FIG. 128.—Plot of a Survey.

clockwise in both cases; but in a given survey it must be read from either north or south only.

185. The deflection angle is the angle formed by the prolongation of a side and the one next succeeding. See Fig. 128. The interior angles of the polygon are supplements of the deflection angles. For a polygon of n sides we know that the sum of the interior angles $=(n-2)\ 180°$. We also know that a deflection angle + its supplement $=180°$, and the total $=n \times 180°$; therefore the sum of the deflection angles $=(n \times 180°)-(n-2)\ 180°$. Thus a check may be had upon the field work.

A survey may be plotted from the deflection angles, as well as from the bearings and azimuths.

186. The record of a survey is made usually in a form similar to the following:

RECORD OF A SURVEY

Course.	Length of Course. Feet.	Bearing.	Remarks.
A–B	1000.0	N. 15° 0′ E.	Large oak tree (*B*)
B–C	1359.8	Due E.	Crossing Brook
C–D	1168.0	S. 7° 40′ W.	Woodland
D–A	1483.6	W. 81° 30′ N.	To point of beginning

A plot of the above survey is shown in Fig. 128. For all ordinary purposes the angles may be laid off with sufficient accuracy by means of a protractor. The lines are drawn in the given direction and the courses laid off to any convenient scale. The termination of the last course should coincide with the point of beginning, thus forming a polygon. Failure of the plot to "close" would indicate error in the data or in the plotting.

The diagram or outline of a plot is the simplest form of topographical drawing.

187. In order to stake out, or survey, a plot of ground it is necessary to use a compass in some form, and a chain or tape. An instrument known as a transit is generally used for "running the lines," i.e., to determine the angles. **A transit** is a kind of telescope set in a frame and mounted on a tripod. See Fig. 129. It is arranged to swing both horizontally and vertically and is provided with levels and adjusting screws. A magnetic needle mounted below the telescope indicates the magnetic meridian, and scales show the degrees of deviation, horizontally and vertically, that the axis of the telescope makes with the horizontal and meridian.

188. The transit is set up at one corner of the plot, designated *the point of beginning*, which is usually denoted by a "monument" or other form of marker. See A, Fig. 128. After the instrument is leveled and adjusted, the bearing of the first course is taken from the meridian or reference line and a rod or *range pole* is sighted on the course. With the tape or chain the given distance is laid off and point B is established. If B is too far distant or if the course is curved, intermediate points are staked.

The transit is then removed and set up at B, after which a "back sight" is taken on A. The instrument is then turned through the required degrees of the bearing or deflection angle and the course to point C is sighted and laid off.

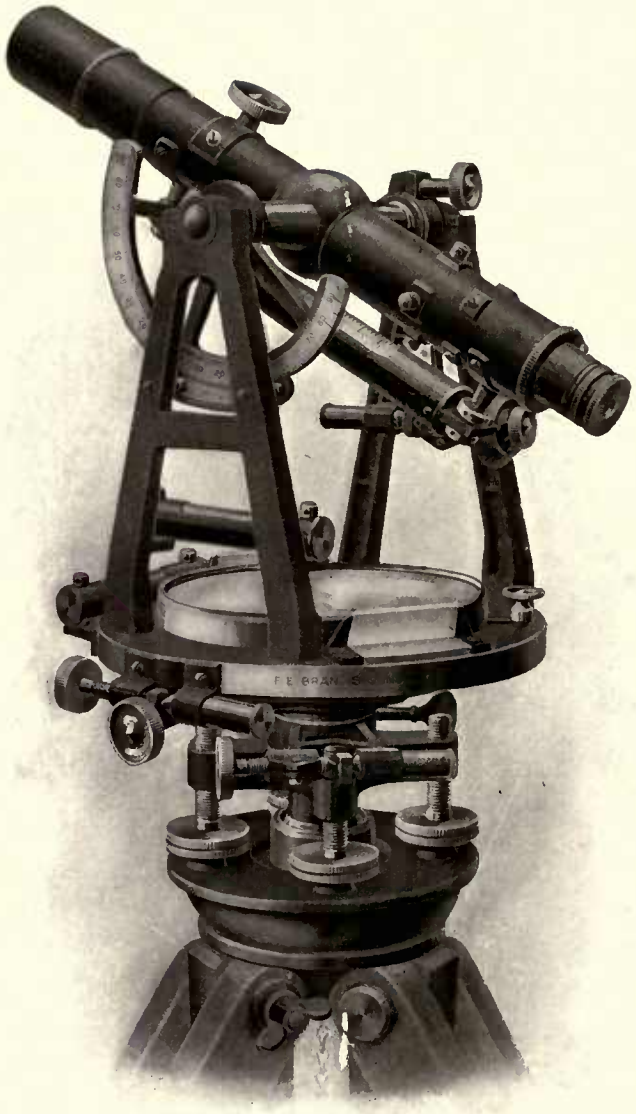


Fig. 129.—A Transit.

The same order of procedure is followed for the remaining courses until the point of beginning is reached and checked. If, instead of the deflection angle, the azimuth —the total angle which the course makes with the meridian—were used, the result would be the same.

189. Greater accuracy may be obtained, when necessary, by employing other and more elaborate methods, involving the use of trigonometric computations, but as nearly all cases within the scope of this treatise may be covered by the simpler method given above, the others are omitted. The order of drafting a plot on paper is precisely the same as that of surveying it.

190. The deed to a property usually contains a description which defines the boundaries, and frequently it is desirable to make a map from the data contained therein. The following description is an abstract from the deed to a farm, and the diagram of the plot in accordance therewith is shown in Fig. 130.

"All that Tract or Parcel of Land, situate in the Town of Newstead, County of Erie, and State of New York, which on a map or survey of divers tracts of land in said county made for the Holland Land Company by Joseph Ellicott, Surveyor, is distinguished as Township Number Twelve (12) in the Fifth (5) Range of said Township. And on another map or survey made as aforesaid of said Township into Sections and Lots is distinguished as part of lots Numbers One (1) and Three (3) in the Thirteenth Section of said Township. Beginning at a point in the East line of said Lot Number One (1) made by the intersection of the center line of the East and West Road with the East line of said Lot and which point is Thirty-eight (38) rods north from the South-east corner of said Lot Number One (1),

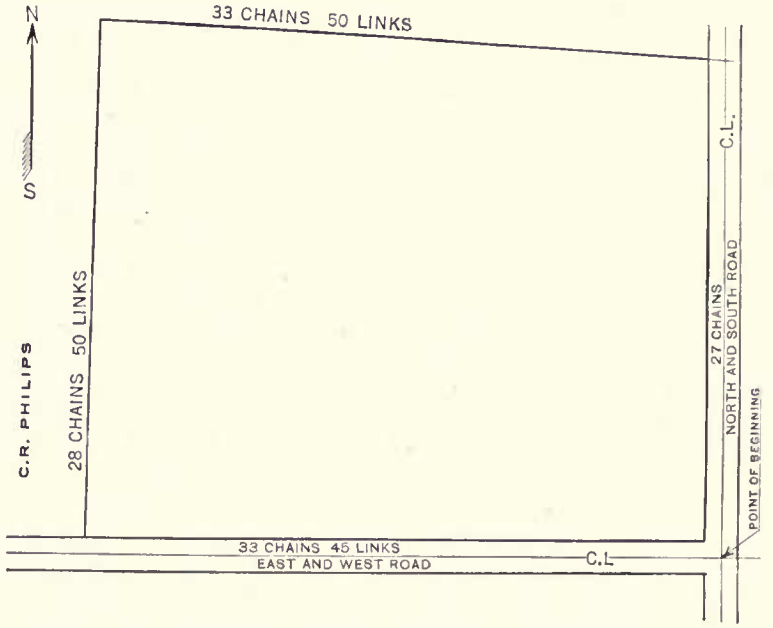


FIG. 130.—Diagram of a Plot from a Title Abstract.

running thence North Twenty-seven chains; thence West Thirty-three chains and Fifty links to the East line of land now or formerly owned by Charles R. Philips; thence South Twenty-eight chains and Fifty links to the center of the East and West Road; thence East along the center line of East and West Road

Thirty-three chains and Forty-five links, more or less, to the place of beginning. Containing Ninety-one acres and fifteen rods of land be the same more or less."

191. A map of a plot should contain all the information essential to establish the legal title to the property, as follows, see Fig. 131:

(*a*) The bearing and length of each boundary.

(*b*) The number of acres in the parcel.

(*c*) The location and description of all markers or monuments.

(*d*) The designation of all important natural features, such as streams, lakes, etc.

(*e*) The designation of all important artificial features, such as highway, railroad, etc., also political boundaries.

(*f*) The names of abutting property owners.

(*g*) The magnetic meridian (north point).

(*h*) Title and certification.

192. The physical features of a tract may be represented to advantage by arbitrary symbols or conventions which are usually more or less suggestive of the part represented. This will be clearly understood by referring to Plate XXXIV and noting the conventions as indicated, which are those most frequently used.

In applying the conventions to a map it is necessary to use good judgment in selecting the scale to which they are to be rendered. They should be drawn neither too

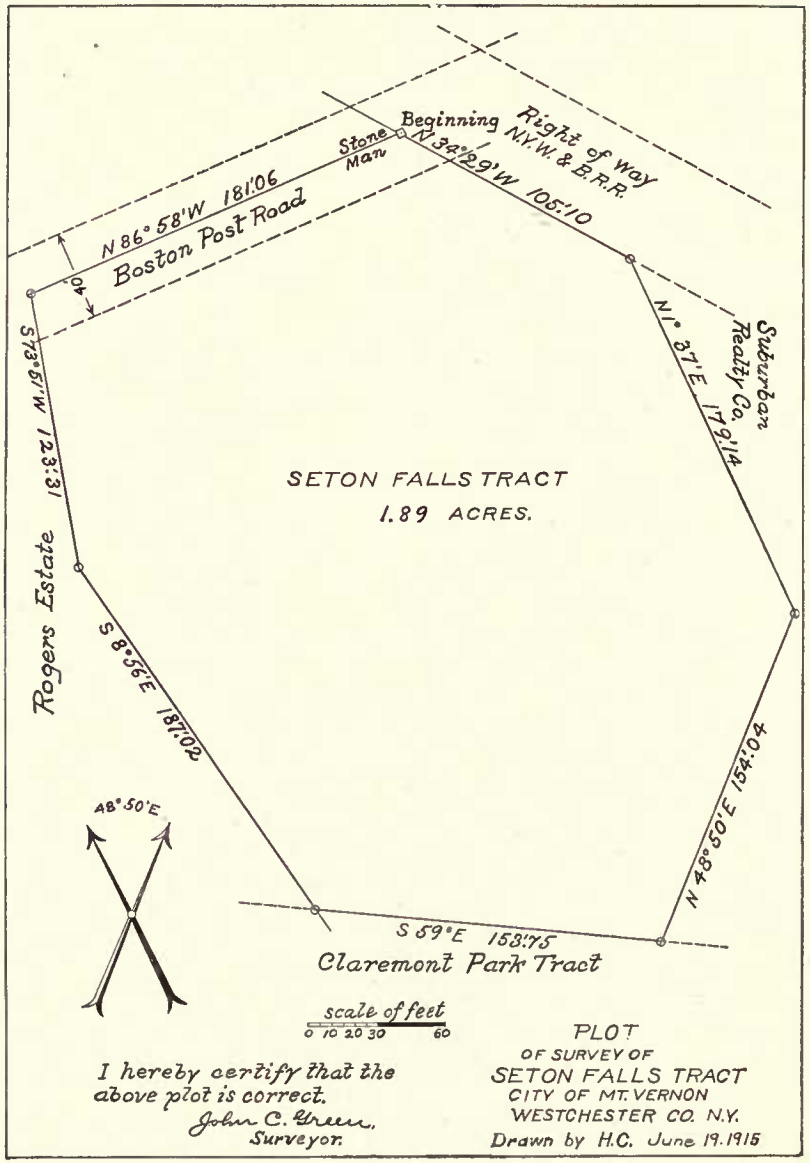
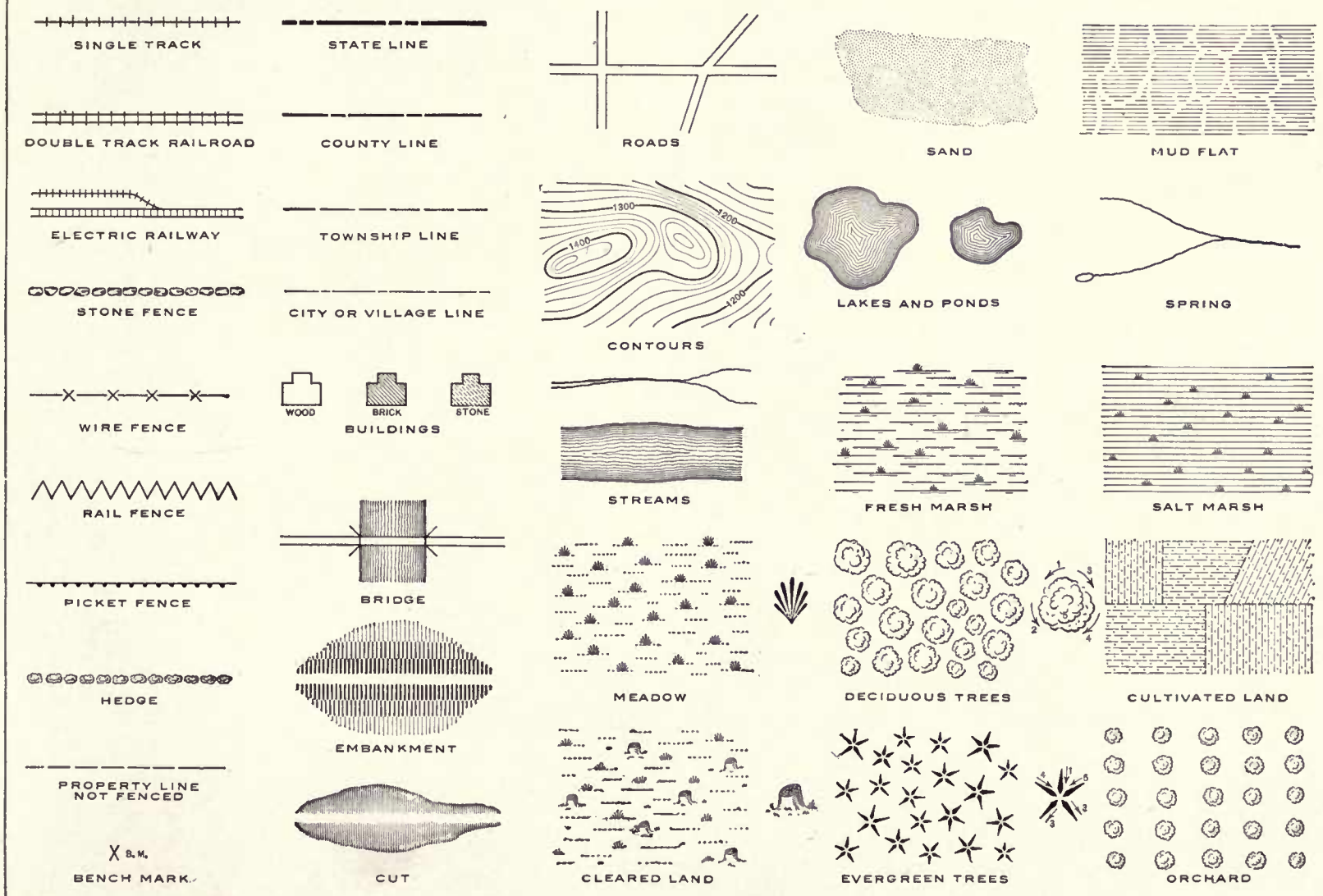
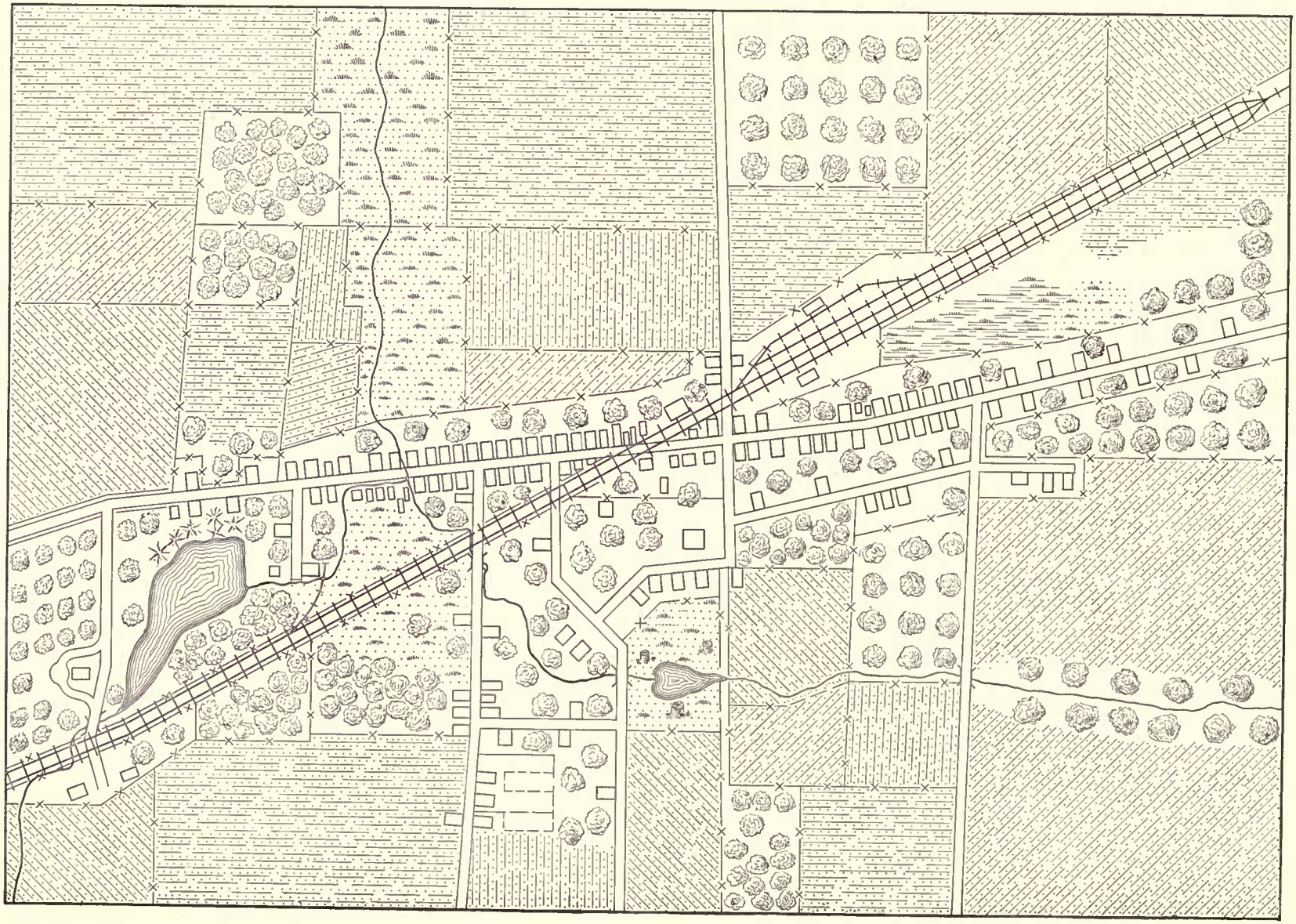
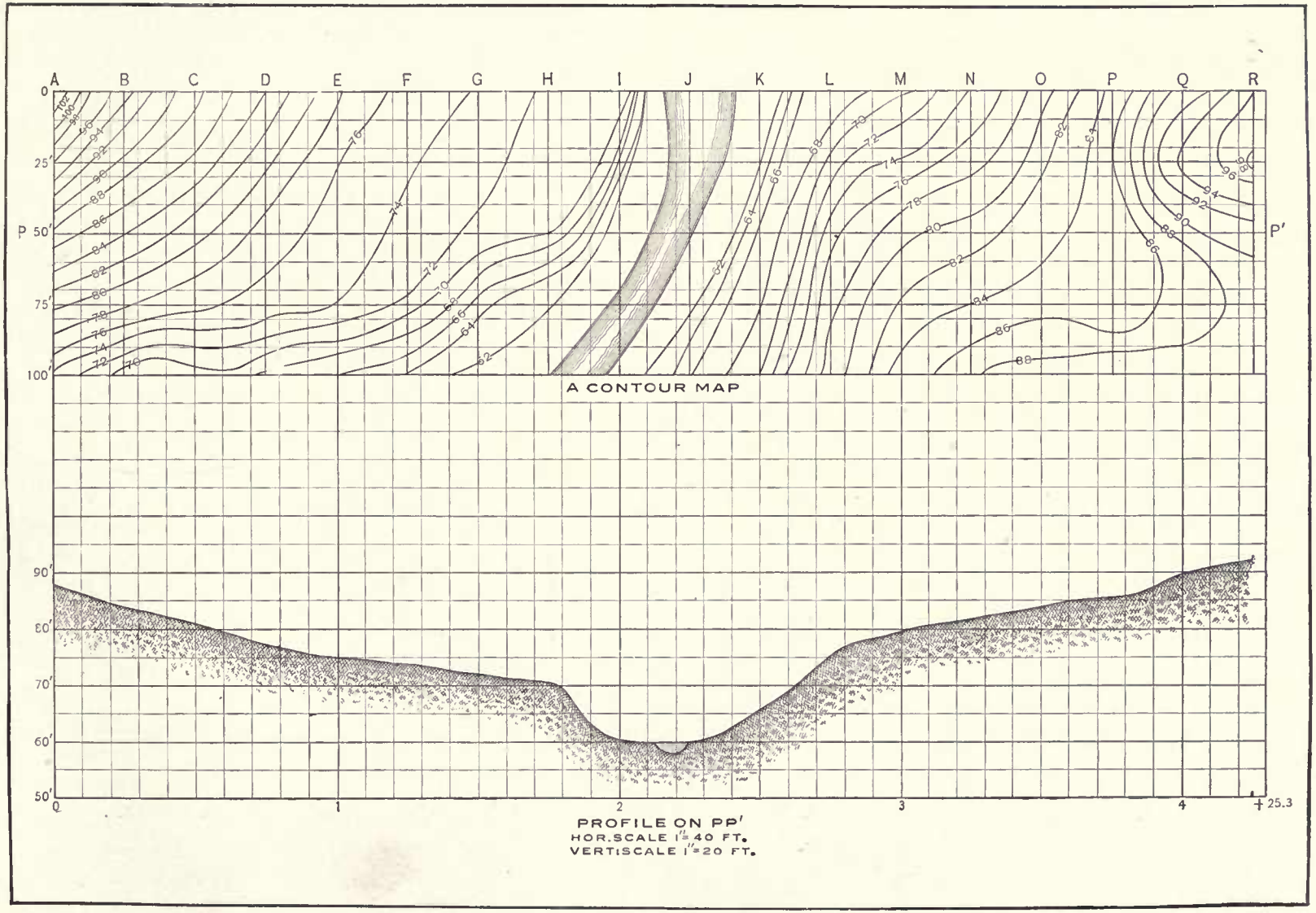


FIG. 131.—Certified Map of a Plot.


SINGLE TRACK
STATE LINE
ROADS
SAND
MUD FLAT
DOUBLE TRACK RAILROAD
COUNTY LINE
ELECTRIC RAILWAY
TOWNSHIP LINE
1300
1200
1400
1200
LAKES AND PONDS
SPRING
STONE FENCE
CITY OR VILLAGE LINE
CONTOURS
WIRE FENCE
WOOD
BRICK
STONE
BUILDINGS
STREAMS
FRESH MARSH
SALT MARSH
RAIL FENCE
BRIDGE
PICKET FENCE
MEADOW
DECIDUOUS TREES
CULTIVATED LAND
HEDGE
EMBANKMENT
PROPERTY LINE NOT FENCED
X B.M.
BENCH MARK
CUT
CLEARED LAND
EVERGREEN TREES
ORCHARD




A B C D E F G H I J K L M N O P Q R
0
25'
P 50'
75'
100'
P'
A CONTOUR MAP
90'
80'
70'
60'
50'
0 1 2 3 4 +25.3
PROFILE ON PP'
HOR. SCALE 1"=40 FT.
VERT. SCALE 1"=20 FT.

large nor too small; good proportion must obtain that no one feature be unduly prominent. Conventions are rendered in India ink and also in color.

A map of a tract rendered in topographical conventions is shown on Plate XXXV.

193. A level surface is one that is parallel with the surface of still water, and a line in such a surface is a **level line.**

The difference of level between two places is the distance in feet, measured vertically, that one place is above the other, and the process of measuring this distance is known as **leveling.**

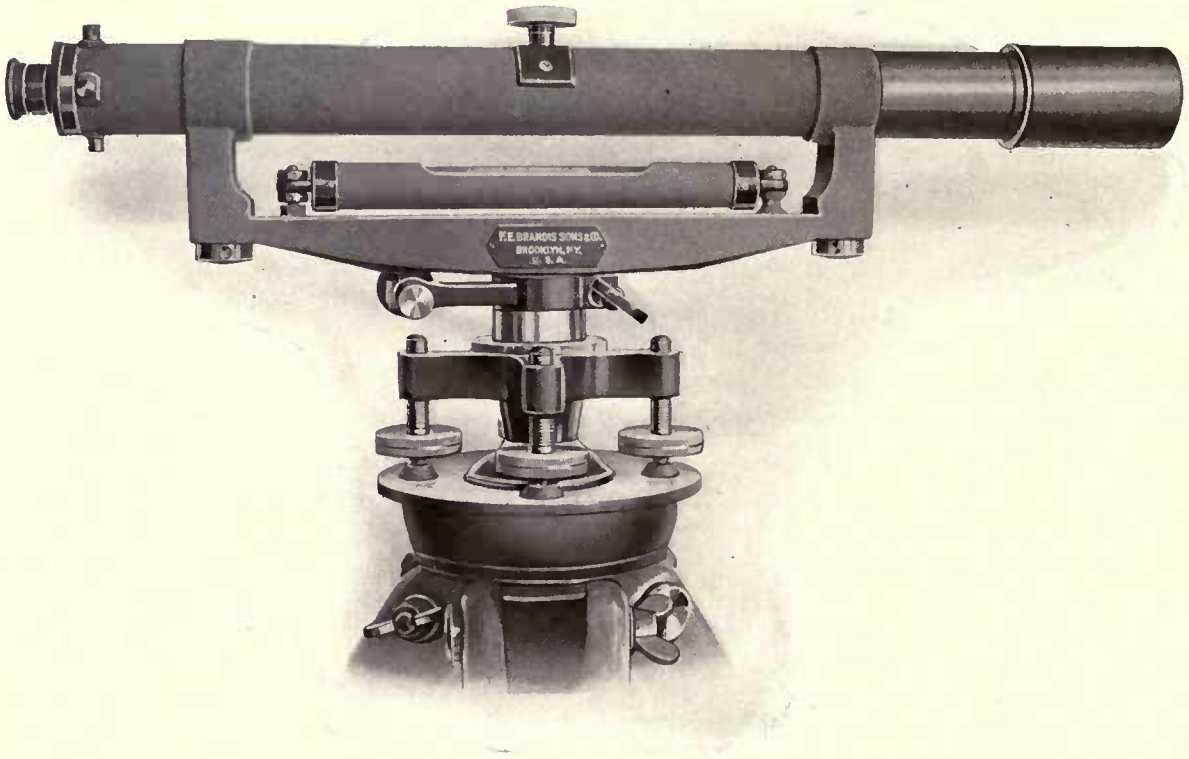


FIG. 132.—A Level.

A section or profile is a representation of the differences in level on a line made by the intersection of a vertical plane with the surface of the earth. See Plate XXXVI.

The scale used for vertical distances on a profile is usually greater than for the horizontal and the result is called an *exaggerated profile.*

194. The elevation of a place is its distance above an assumed horizontal plane, called the **datum plane.** The position of the datum plane is fixed with reference to some permanent object called a **bench mark.** All distances above

FIG. 133.—A Leveling Rod.

the datum plane are +, and below are −, but in order to avoid negative heights, the datum plane or base line is often assumed at such a distance below the B.M. that all the points of the section shall be above it.

The level of the sea is largely used as an established datum plane for comparative reference. Thus a place designated as "El. 123.4" is 123.4 feet above the sea level or datum plane, and "El. −23.0" indicates that the place is 23.0 feet below the datum.

Stations are points at which the elevations are measured. They are usually taken at 100-foot intervals along the base line

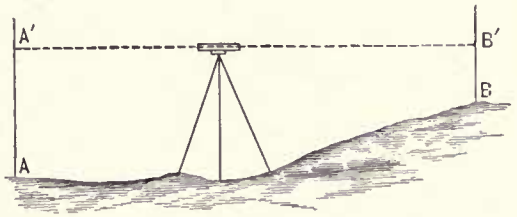


FIG. 134.—Method of Determining Difference in Level.

and are designated 0, 1, 2, 3, etc. A point between stations is described thus, "Sta. 4+25.3."

195. Elevations are determined by means of the *level and leveling rod* and the horizontal distances between stations are measured with a chain or tape.

A level of the ordinary type used by surveyors is shown in Fig. 132. Fairly accurate results may also be obtained

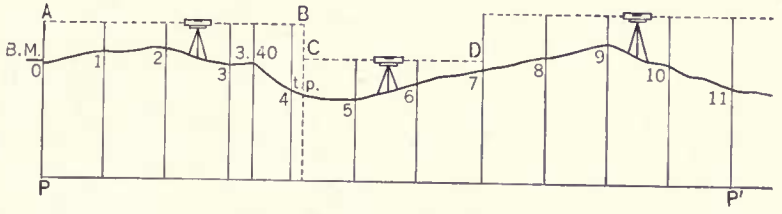


FIG. 135.—Running a Level.

by using the transit as a level. A leveling rod is shown in Fig. 133.

196. To determine the difference in level between two points the instrument is set up as shown in Fig. 134. The leveling rod is set at A and the height of A′ is noted, and in like manner BB′ is measured. The difference between AA′ and BB′ is the difference in level between A and B.

197. The method of obtaining the necessary **field notes** for making a profile is indicated in Fig. 135. The stakes are set at 0, 1, 2, 3, etc. The level is set up at a convenient point and readings are taken on the B.M. and stations. P*o* is the distance of the datum plane to the B.M. and if to this be added the distance *o*A the result will give the **height of instrument** (H.I.) from the datum plane to the line of sight (AB). It is evident that if the

rod readings are subtracted from H.I. in each case the result must be the elevation (El.).

198. When it is necessary to change the position of the level a convenient point is located for a *turning point* (t.p.). The point on which the last sight is taken before changing the position of the instrument, and the first sight from the new position, is called a **turning point.** Readings are taken as before and the process is continued until a sufficient number of lines have been run to secure the required data.

The record of the work is kept in a " field book " as follows:

LEVEL NOTES

Station. Sta.	Back Sight. B. S.	Height of Instrument. H. I.	Fore Sight. F. S.	Elevation. El.	Remarks.
B.M.					
0	11.406	111.406	.....	100	X in rock opp.
1	.....	.....	6.3	105.1	stone bridge
2	.....	.....	9.5	101.9	N. side of
3	.....	.....	8.2	103.2	brook.
4	.....	.....	7.0	104.4	
5	.....	.....	2.5	108.9	
t.p.	10.944	119.962	2.388	109.018	X in rock 2′
6	.....	.....	6.2	113.7	± W. of sta.
7	.....	.....	2.1	117.8	A_6.
t.p.	11.381	129.329	2.014	117.948	X in rock 7′±
8	.....	.....	3.5	125.8	S. W. of sta.
9	.....	.....	3.3	126.0	A_8.

199. Explanation of Level Notes. " Sta." (station)—all points on which sights are taken.

" B.S.",—denotes readings on bench marks and turning points.

" H.I.",—the height of instrument, found by adding B.S. to the distance (El.) of B.M. or t.p. above the datum plane.

" F.S.",—this column contains all readings except those noted in " B.S."

" El." is determined by subtracting B.S. or F.S. from H.I.

200. The profile is constructed by drawing a base line and erecting perpendiculars at intervals corresponding to the stations. The elevations are then laid off and through the points thus found an irregular line is drawn free-hand. This work is facilitated by the use of a regular co-ordinate paper known as *profile paper.*

201. A contour is a line formed by the intersection of a horizontal plane with the surface of the ground, as, for example, the shore line of a lake. If the level of the water in the lake should drop 2 feet, a new shore line or contour would be formed with a 2-foot *contour interval.*

It is evident that a contour line is more or less irregular in form, and also that all points through which it passes are at the same elevation. Hence, it is only necessary to find points at the same level and join them, to determine a line of intersection or contour. A series of contour

lines represent the intersection of several parallel horizontal planes with the earth's surface and collectively constitute a **contour map.** See Plate XXXVI.

It is evident that the more rapid the rise in the ground or change in level, the nearer the lines will approach to each other, but it should be noted that they do not cross. If they come together it indicates a vertical surface. *The elevation of a given contour is designated on the map by placing the reference number within a break in the line.*

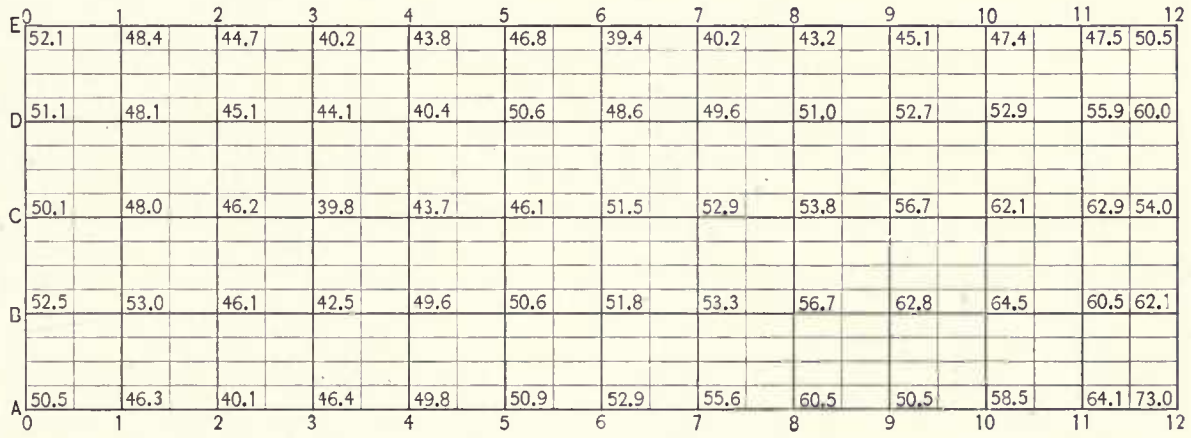


FIG. 136.—Level Data.

202. To secure data for a contour map, several lines of levels have to be run. With the notes and data in hand, the map is made by locating or plotting the points on co-ordinate paper and drawing lines freehand through the given points.

The method of recording the data on co-ordinate paper is shown in Fig. 136.

By joining all points of the same elevation a series of contours may be found. This is done by "interpolation," i.e., by determining by inspection the location of required points through which the lines should pass. A profile may be readily plotted from a contour map or from the data by which such a map is constructed.

203. The topographical features of a portion of country near Whitehall, N. Y., are well shown in Fig. 137, and a topographical map of the same region, shown in Fig. 138, is a typical representation of its character. This map is from a United States Geological Survey Map.

The purpose of a contour and profile map is to determine the flow of water or drainage, cuts, fills, and grades in road building and other construction work.

204. A grade line or gradient is a line connecting places of different levels for the purpose of determining the distances that the leveling stations are above or below grade. It is indicated on the profile; also on the plan, as the center

line of roadways and similar forms of construction. Grade lines are established on the basis of the rise or fall per hundred feet of length and are denoted by the term "per cent." A grade of +1.5 would indicate a rise of $1\frac{1}{2}$ feet in 100 feet of its length, and −3.0 would mean a fall of 3 feet in the same distance.

FIG. 137.—View of Country near Whitehall, N. Y.

205. Cut and fill are terms denoting the excavation and filling in required on road building and similar construction. This is shown in Fig. 139.

The slope of the sides, or *batter*, is determined by the *angle of repose* of the given material. It is expressed by a ratio, as 2 : 1, $1\frac{1}{2}$: 1, etc.

206. The amounts of cut and fill are determined by drawing a base line upon which the stations are laid off. At each station a section is taken, similar to (*a*) and (*c*)

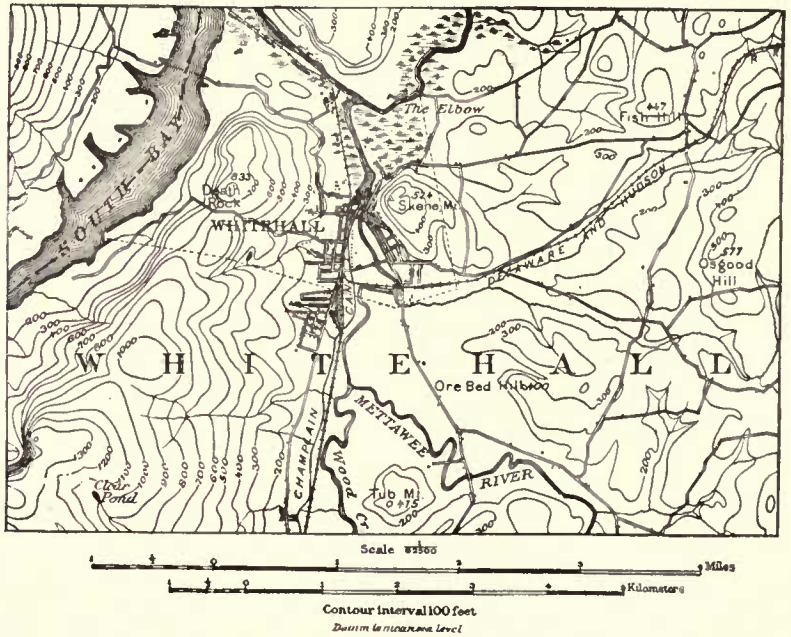


FIG. 138.—Topography of Whitehall and Vicinity.

Fig. 139. The earth between any two sections forms a solid called a *prismoid* the volume of which may be determined by the prismoidal formula, as follows:

Let A_1 = the area of one section, or end;

A_2 = the area of other end;

A_m = the area of mid-section;

h = the perpendicular distance between ends.

Then $$V = \frac{h}{6 \times 27}(A + 4A_m + A_2) = \text{volume in cu.yds.}$$

The areas of the sections may be found usually by dividing them into triangles, and trapezoids.

For approximate results the formula may be written,

$$v = \frac{h}{27} \times \frac{A_1 + A_2}{2} = \text{cubic yards.}$$

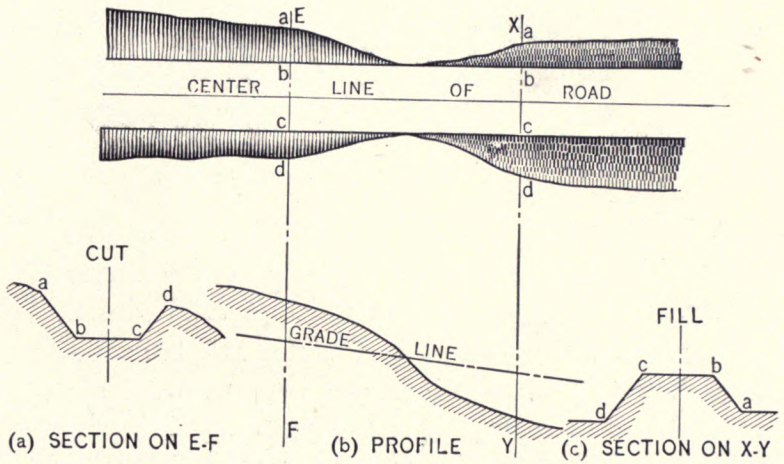


FIG. 139.—Representation of Cut and Fill.

CHAPTER IX

PICTORIAL REPRESENTATION AND SKETCHING

207. In Chapter II, paragraph 47, it was explained that an object may be represented by several kinds of drawings. In mechanical drawing the method of orthographic projection, explained in Chapter III, is generally employed, but it is sometimes necessary to make a pictorial drawing of an object. For this purpose either **perspective** or **isometric** drawing may be used. The former represents the object more truly, but the latter is made much more quickly. (Compare Figs. 18 and 19.) Both methods are explained in the following paragraphs.

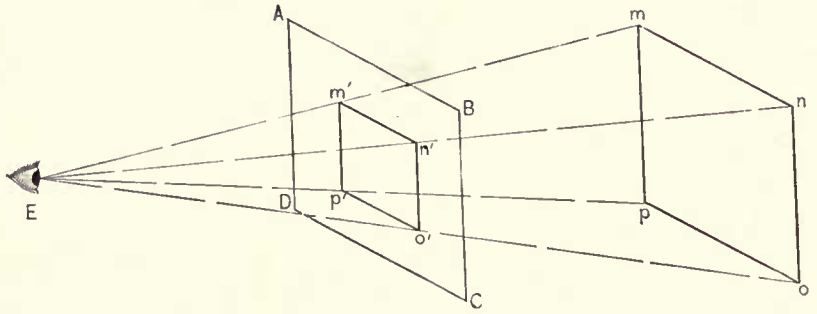


FIG. 140.—A Perspective Projection.

208. Mechanical Perspective. It is beyond the scope of this book to give a complete treatment of this subject; only the fundamental principles in their simplest form and application will be given.

If a thin piece of card-board or tin is held up before the eye as shown in Fig. 140, *mnop*, a ray of light is projected from each corner to the point of sight. A pane of glass held between the eye and the object, as ABCD, would be pierced by these rays at the points $m'n'o'p'$. The figure formed by joining these points has the same appearance to the eye as the original object, if held in the same relative position, and is called a **perspective.**

The artist represents the object in perspective by sketching each line as it appears to the eye.

209. A perspective projection may be obtained as described in paragraph 208, but this is not a practical drafting-room method. Mechanical perspective may be considered as a problem in projection and as related to orthographic projection. This relation will be apparent by referring to Fig. 141.

The object is behind and touching the transparent vertical plane V and the eye of the observer is at E. The

outline of the perspective is determined by the projecting rays or lines, from the corners of the object to the eye, intersecting V. The perspective, therefore, is a representation of the object and the eye of the observer upon V.

210. The method of mechanical perspective is first to find the orthographic projections of the object upon V and H, then to find the intersections of lines from points on the object to the eye with V. These are points where the lines pierce V, and, joined together, form the perspective.

The object shown in Fig. 141 is placed purposely with its front face in V so as to make the problem as simple as possible. The top view, therefore, has one edge in GL; also it is seen that the front view in orthographic projection coincides with the same view in perspective. The eye, E, of the observer is taken at a point *in front of* V *and in* H, its V projection is therefore in GL, at E_V, and its H projection is *below* GL, at E_H. This must be so, because E is *in front of* V.

It should be noted that E_H is situated in H *extended in front of* V.

211. A ray of light passing in space from *a* to E, Fig. 141, would pierce V at some point O. Therefore, to obtain the perspective of a point, as A, the method would be to **determine the projections of its ray of light and thus determine where the ray pierces** V. This may be done as follows: Draw $a_H E_H$, the H projection of *a*E, intersecting GL at O_H. Now O_H must be the H projection of the point where the line *a*E pierces V, therefore, its V

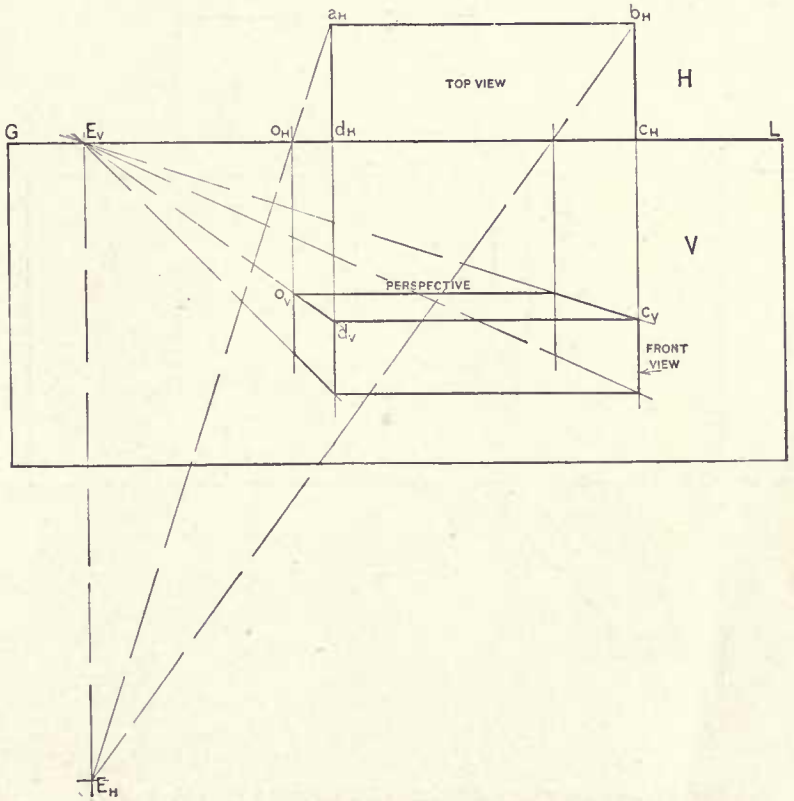


FIG. 141.—Showing Relation of Perspective to Orthographic Projection.

projection will be in a vertical line below O_H. Draw $E_V d_V$, the V projection of *a*E; the intersection of the vertical

line with $E_V d_V$ gives o_V, which is the perspective of the point *a*.

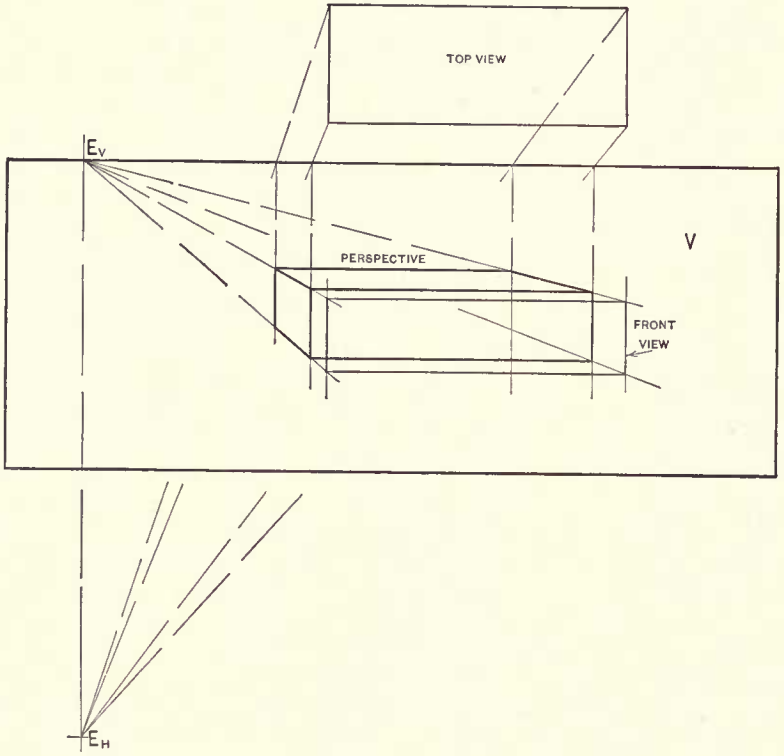


FIG. 142.—Perspective of Object with its Front Face back of V.

212. If the object is placed with its front face back of V, the method of procedure is the same, provided it is parallel to V, but more lines are required to determine the perspective. The resulting perspective, however, is smaller than before. See Fig. 142.

The position of the front view relative to GL is important, as determining the perspective of the top; the nearer it is placed to GL the smaller the top will be in perspective. If placed above GL, the bottom would be shown.

213. If the eye is placed *below* H instead of *in it*, the method is no different, but the perspective is slightly altered as shown in Fig. 143. It is easily seen that the perspective changes as the position of the eye changes.

Thus far this subject has been discussed not only as a problem in orthographic projection, but also in the same terminology. It has characteristic terms, however, which will now be defined and hereafter employed, although it will still be regarded as a problem in orthographic projection.

214. The picture plane (PP) is the plane on which the perspective is drawn; this may be the same as V.

The horizon line (HL) is a horizontal line on the level with the eye and lying in the picture plane; it is the intersection of the **horizon plane** with the picture plane. The horizon plane and H may or may not be the same. See Fig. 143.

The point of sight is the position of the eye; it is always somewhere within the horizon plane. It is designated as E or S, and its projections are E_V and E_H, or S_V and S_H.

A good location for the point of sight should be selected, as the character of the perspective depends upon it. It is usually taken about 10″ or 12″ in front of the picture plane, or the reading distance from the eye. In the illustration shown in this book this distance is much less on account of the limitations of the page, and the perspectives are accordingly " steep."

215. A vanishing point (V) is a point toward which all parallel lines converge in perspective. This point in all cases thus far shown has been E_V.

All horizontal lines vanish in the horizon and lines that are parallel in the object vanish to the same point.

Lines that are parallel to the PP are not drawn to a vanishing point in the perspective, because the convergence is exceedingly small within the limits of the picture.

Lines that are perpendicular to PP converge toward E_V.

Horizontal lines that are oblique to PP converge toward points on either side of E_V, designated as vanishing points V_1 and V_2. See Fig. 144.

216. The vanishing point for a horizontal group of lines is found by drawing through the horizontal projection of the point of sight (E_H) a line parallel to the horizontal projections (top view) of the group, as shown in Fig. 144. If the lines make an angle of 45° with PP, the vanishing points will be equidistant from E_V and at a distance from it equal to $E_V E_H$.

217. It is customary to place the object to be drawn with one of its faces or edges in the picture plane; this simplifies the problem, because *all measurements must be made in the picture plane.*

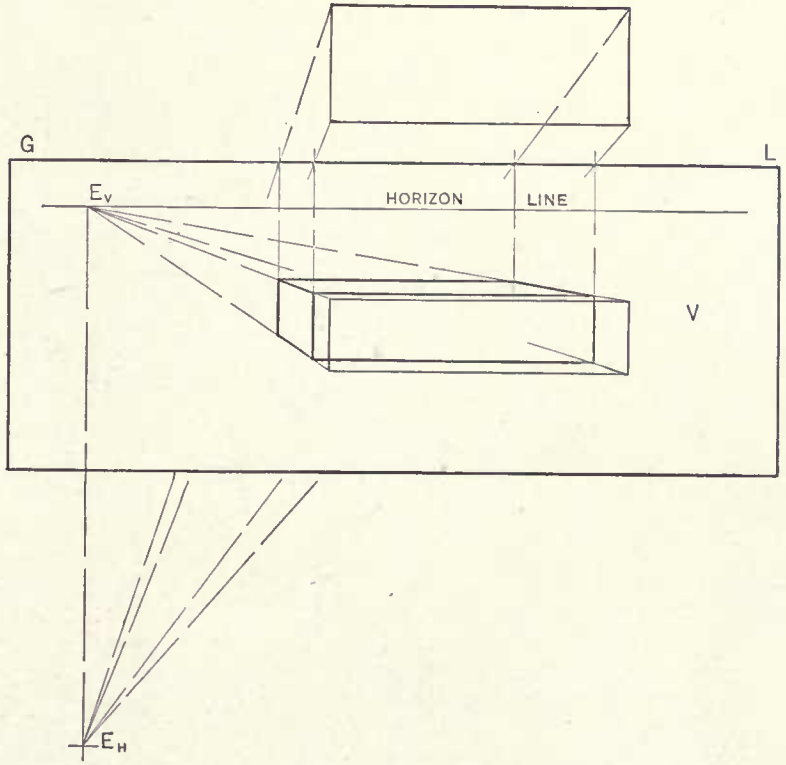


FIG. 143.—Perspective of Object with Eye placed below H.

The use made of the front view is only that of obtaining the vertical heights or measurements, therefore

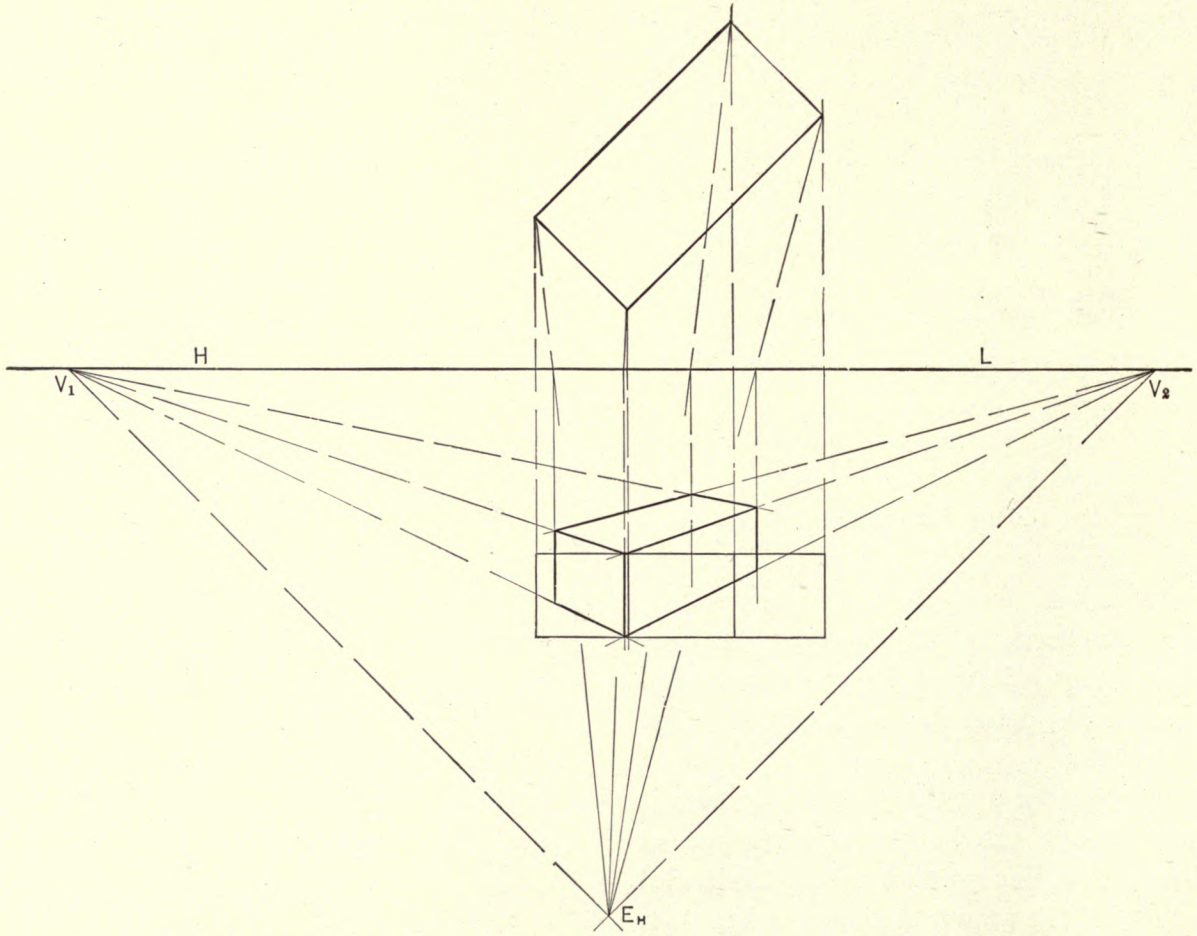


FIG. 144.—Perspective with Parallel Lines converging to Vanishing Points.

the side view would serve the same purpose; thus the front view may be omitted and the space kept free for the perspective. See Fig. 145.

218. From the principles stated in the foregoing paragraphs and exemplified in Fig. 144, the order to be followed in making a perspective may be summarized as follows:

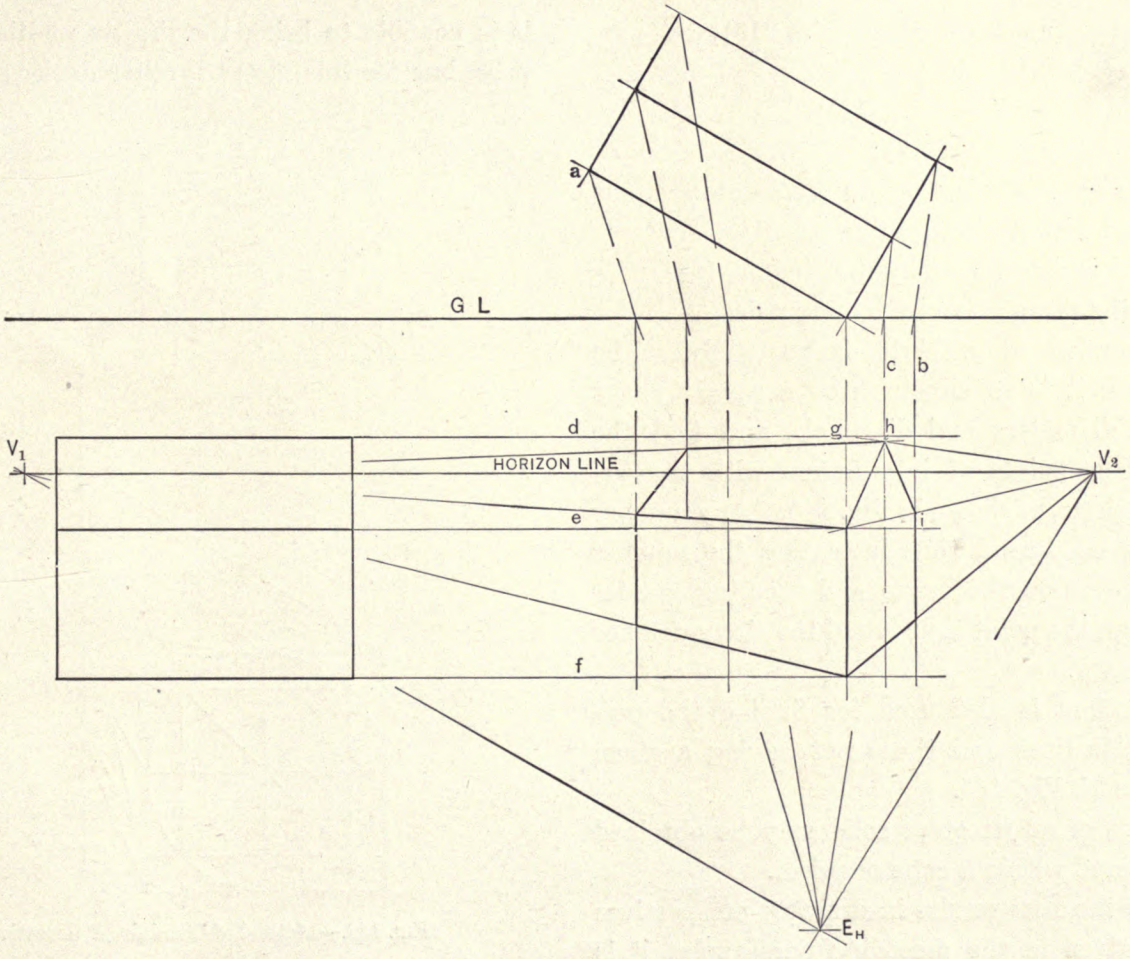


FIG. 145.—Perspective drawn with aid of Side View instead of Front View.

(*a*) Draw HL (214);
(*b*) Draw the top view (210, 217);
(*c*) Draw the side view (210, 217);
(*d*) Locate the point of sight (210, 214);

(*e*) Determine the vanishing points (215, 216);

(*f*) Draw aE_H, etc. (210, 211);

(*g*) Draw vertical lines *b*, *c*, etc. (211);

(*h*) Draw horizontals *d*, *e*, *f* (217);

(*i*) Draw lines to vanishing points from intersections of vertical with horizontal lines (215);

(*j*) Note that *h* is determined by drawing gv_2 (217);

(*k*) Complete the perspective by joining points.

219. The perspective of a circle is an ellipse. The method of drawing it is to circumscribe a square about the circle, draw diameters and diagonals, and find the perspectives of their points of intersection with the circumference of the circle, as shown in Fig. 146. Any number of diameters may be drawn, thus increasing the number of points that determine the curve and securing greater accuracy. Through the point thus found the circumference of the ellipse is drawn.

The above method is also used for finding the perspective of irregular lines and those not having a given vanishing point, as *hi*, Fig. 145.

The perspective of an irregular solid may be obtained by drawing it inclosed within a cube or prism.

220. To secure the best results in drawing perspectives by the methods given in the preceding paragraphs, it is necessary to use a drawing board and paper of ample dimensions; this is feasible, however, within reason.

By means of using what are termed " measuring points " it is possible to bring the drawing within a smaller compass, but for this method, other devices and special cases,

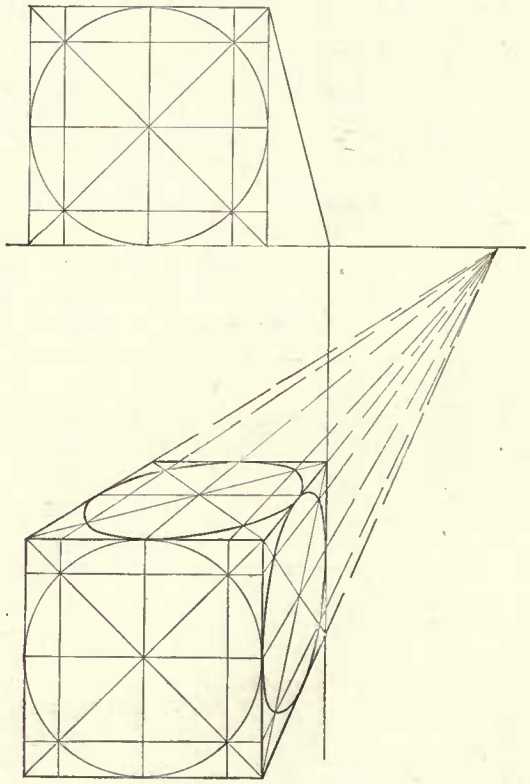


FIG. 146.—Method of Obtaining Perspective of a Circle.

the student is referred to texts covering a complete treatment of the subject. The object here has been to furnish a method for the solution of simple problems.

221. Isometric Drawing. The pictorial representation of an object by the perspective method requires considerable time and labor, and although it shows the object as it appears to the eye, the lines cannot be directly measured.

The isometric drawing is sometimes used to obtain a pictorial effect. It looks distorted when compared with the perspective, but it is more quickly made and may be scaled.

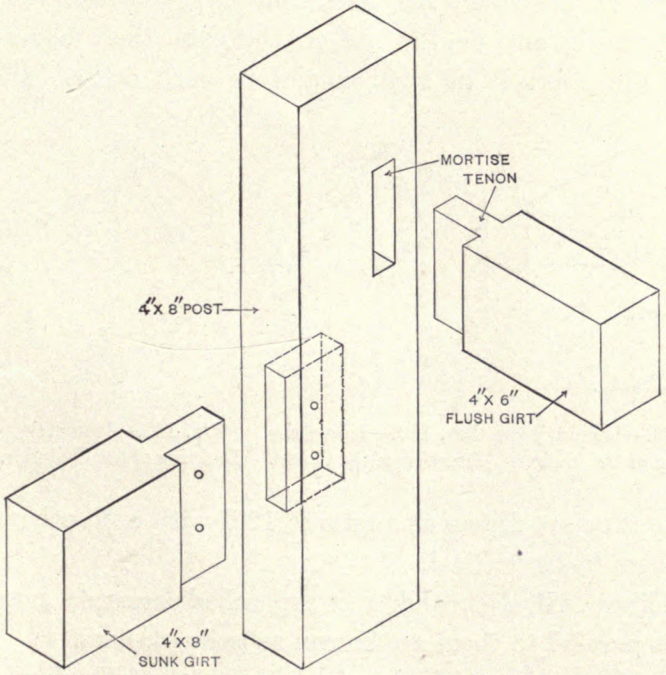


FIG. 147.—Isometric Drawing of Building Details.

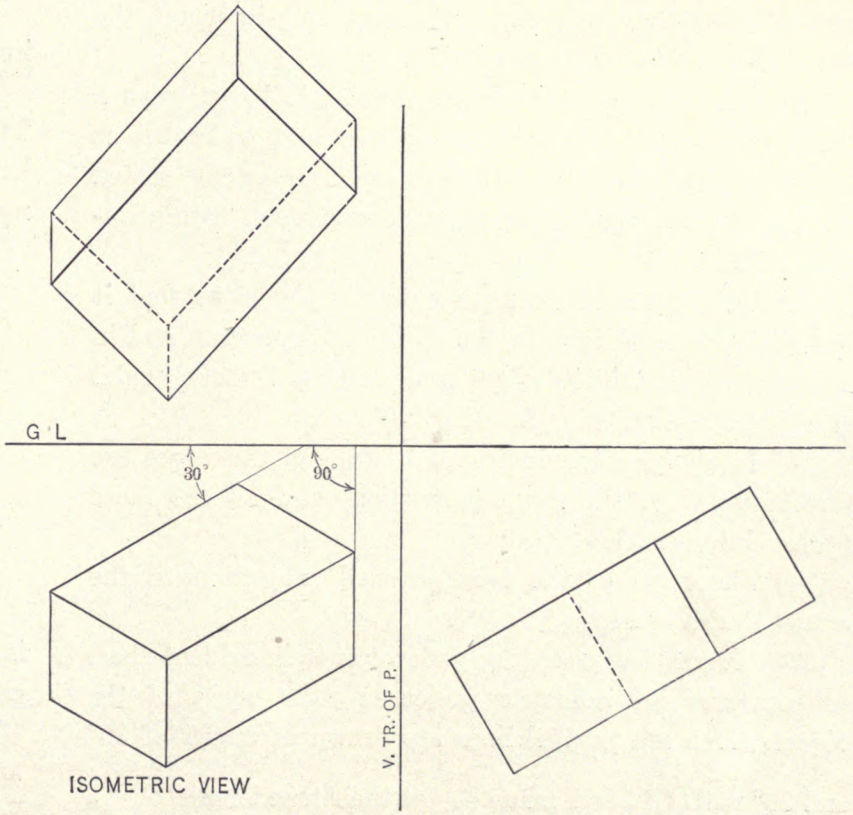


FIG. 148.—Object Drawn in Isometric Projection.

Drawings for construction are usually made in projection, but isometric serves a useful purpose, particularly in connection with building details. See Fig. 147.

Within its scope isometric drawing serves many useful purposes; it is particularly helpful in assisting the student and non-technical person to visualize and interpret the drawing in orthographic projection.

222. The theory of isometric drawing is based upon a special case of orthographic projection and is known as **isometric projection.** The principles will be briefly stated here, as the application does not depend upon their demonstration.

(*a*) The object to be represented is placed so that it has all its faces oblique to the planes of projection and in a position such that its edges projected on V make angles of 30° or 90° with GL. See Fig. 148.

(*b*) In the position indicated in (*a*), all the edges are foreshortened in the same proportion, and all the faces project into one view.

(*c*) The ratio of the foreshortened projection to the actual length of line is 81 : 100.

223. From the preceding paragraph it is evident that, to construct an isometric projection, the edges of the object which are parallel lines are drawn at angles of 30° and 90° with GL, and made $\frac{81}{100}$ of their true length.

It is easily seen that to draw lines measured $\frac{81}{100}$ of their true length would require a special scale. To avoid this the standard scale is used, although the resulting drawing is slightly larger. The latter is designated **isometric drawing.**

The method of isometric drawing is best exemplified in the representation of a cube.

224. The isometric of a cube is shown in Fig. 149. The edges of the cube, AB, BC, and BD, represent its height, breadth, and depth, and on the cube these edges meet in the point B at right angles to each other. In isometric they are drawn at angles of 120° with each other, one of them being vertical.

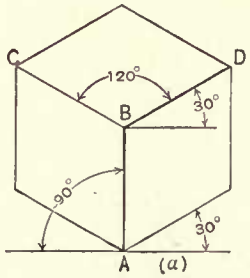


FIG. 149.—Isometric Drawing of the Cube.

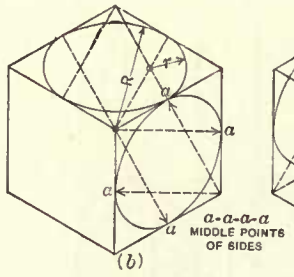


FIG. 150.—Isometric Drawing of the Circle.

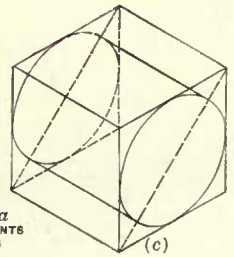


FIG. 152.—Isometric Drawing of the Cylinder.

The lines AB, BC, and BD are called **isometric axes** and lines parallel to them are known as **isometric lines.**

In making an isometric drawing observe the following:

(*a*) Measurements are made to scale and are laid off on the axes or isometric lines only.

(*b*) Lines of the object which are vertical are drawn vertical; parallel lines are drawn parallel.

(*c*) Invisible edges usually are omitted.

(*d*) Shade the lines dividing the surfaces which are illuminated from those in shadow; assume the light to come from the left at an angle of 45°.

(*e*) The isometric of a circle is an ellipse and may be

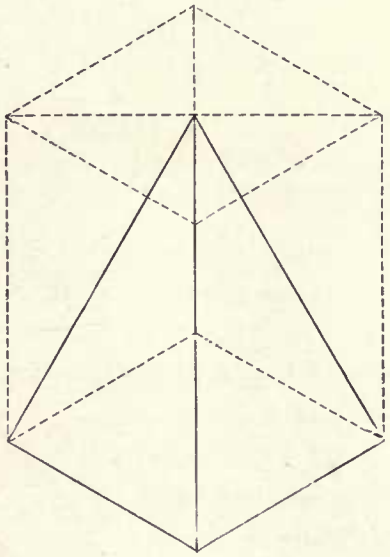


FIG. 151.—Isometric of a Pyramid, showing how Non-isometric Lines are Obtained.

drawn by trammels or any usual method, but ordinarily the approximate method will suffice. This is shown in Fig. 150.

225. The principles of isometric stated above will cover all ordinary cases. Irregular figures may be drawn by determining the location of points in isometric and joining them.

Lines that are not parallel to the isometric axes are known as **non-isometric lines.** They are easily determined as shown in Fig. 151.

The isometric of a cylinder is determined as shown

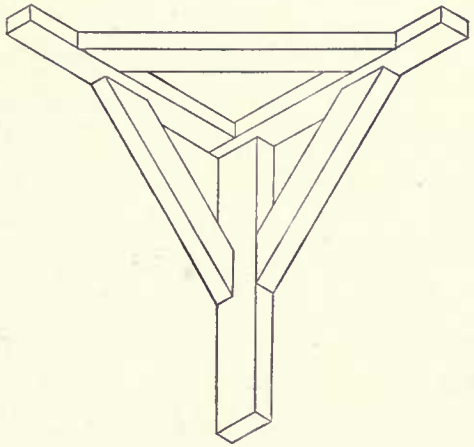


FIG. 153.—An Isometric from below.

in Fig. 152. Note that the elements of the inscribed cylinder are drawn tangent to the ellipses.

Angles cannot be drawn full size in isometric. They must be laid off by points measured on isometric lines.

226. Reversed axes are frequently used, as shown on Plate XVIII. If taken in the normal direction the construction would appear as in Fig. 153. Thus the view

can be made to appear as if looked at from above or below as desired.

Occasionally an isometric drawing is made as shown in Fig. 154 in order to show related parts that are joined obliquely.

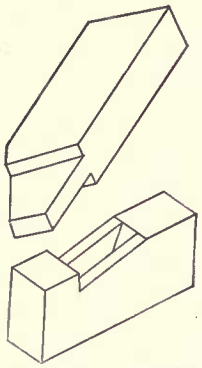


Fig. 154.—Isometric showing Related Parts.

A section or broken end should be drawn in isometric as shown in the various illustrations.

227. Oblique projection is a form of representation in which one face of the object is shown parallel to the plane of projection. The faces which are perpendicular to the plane of projection are represented by lines drawn usually at 30°. See Fig. 155.

This form of drawing is similar to isometric and has the advantage of having one face of the object drawn in its true shape and size. On the other hand the distorted appearance of an isometric is intensified in the oblique drawing; compare Fig. 155 with Fig. 148.

Measurements are laid off on the oblique lines full size the same as in isometric.

228. It is particularly advantageous to draw one face of the object in its true shape and size if it has considerable detail, or if it is irregular in form. Such a face should always be taken parallel to the plane of projection.

It is also important, if possible, to arrange the drawing so that its long axis is parallel to the plane of projection. This will be understood by comparing Figs. 155 and 156, which are drawings of the same object made to the same scale.

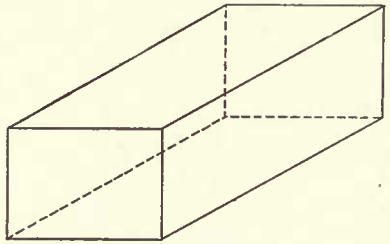


Fig. 155.—Oblique Projection.

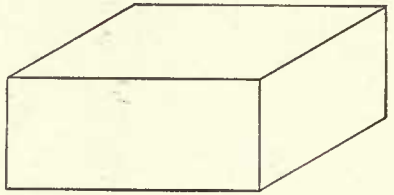


Fig. 156.—Same as Fig. 155 but having long Face Parallel to the Plane of Projection.

229. Cabinet drawing is a form of oblique projection having the faces which are perpendicular to the plane of projection represented by lines drawn usually at 45° and measured *one-half* their true length. See Fig. 157.

The object of this drawing is to overcome as far as possible the effect of excessive distortion and still retain the advantage of representing one face without foreshortening.

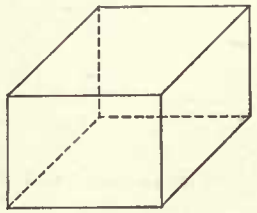
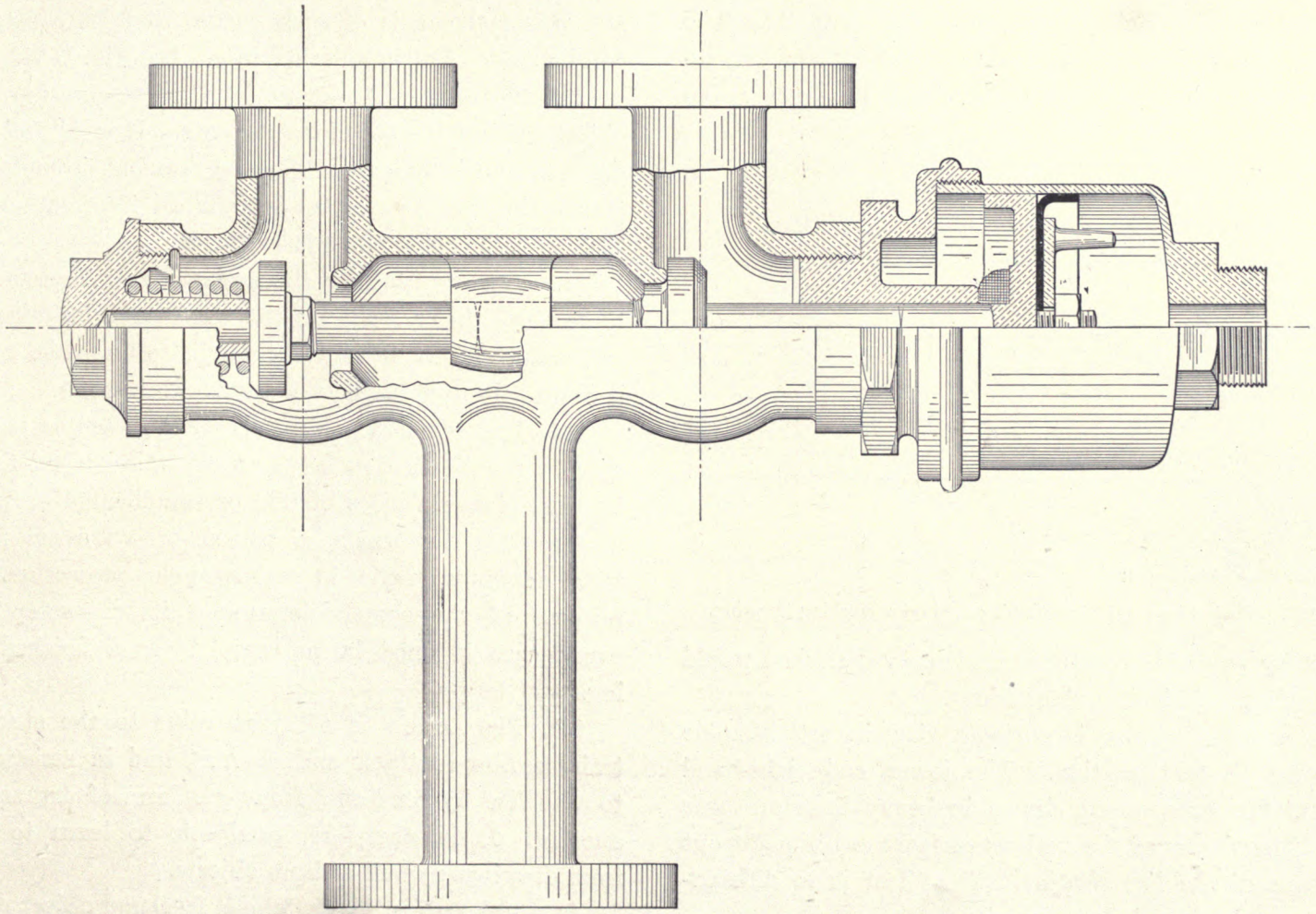


Fig. 157.—A Cabinet Drawing.

In oblique projection, circles and irregular outlines are determined by locating points and drawing the required lines through them in a manner similar to that described for isometric drawing in paragraphs 224 (*e*) and 225.



230. Shade Lines and Line Shading. A pictorial effect is attained to some extent by the employment of shade lines and line shading as shown on Plate XXXVII. The purpose of this drawing is to give a clear idea of the detailed construction and operation of the apparatus. To

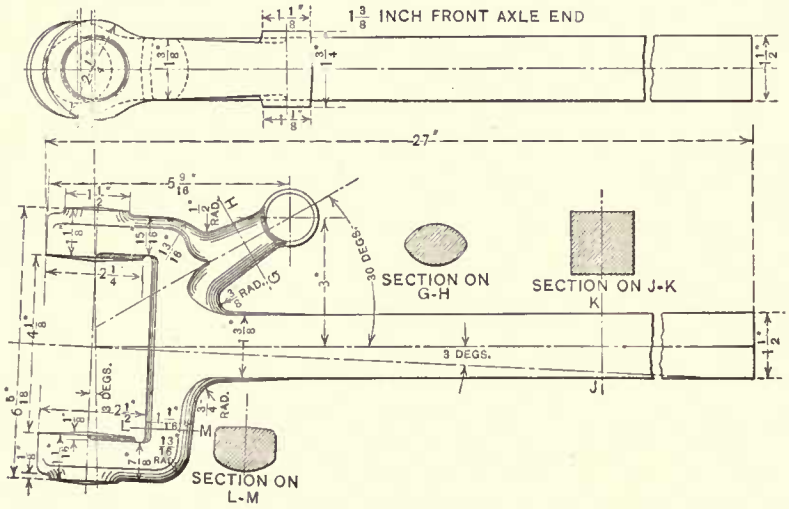


FIG. 158.—Shade Lines and Line Shading used on a Working Drawing.

show it by any of the methods previously described would be exceedingly difficult and laborious.

The drawing shown is a single view in orthographic projection in part section. The lower and right-hand edges of the surfaces are drawn in heavy lines or *shade lines*. The shapes of the various surfaces are brought out by means of the *line shading*. The effect is to differentiate the surfaces and give them form.

Shade lines and shading are not generally employed on working drawings. They should not be used unless the object shown is of such nature that its construction can be made clear in no other way. See Fig. 158.

231. Sketching. A sketch is a representation of an object without the use of instruments. It is a " freehand " drawing and includes the working drawing, isometric, and perspective, but its purpose is technical information rather than artistic expression, as used here.

Sketches are used by the designer as memoranda and to explain the notes; by the draftsman for emergency and repair work. If only one part is to be made, a sketch is frequently used in place of a finished drawing.

232. The isometric or perspective sketch is used frequently for illustration or as an explanatory aid to assist in representing a piece of odd or complicated shape, also at times for the benefit of persons who are not familiar with drawings made in orthographic projection. The purpose of the sketch determines its character, but in every case it must be as complete as a finished drawing.

233. The sketch is of great value to the student in training him to think and observe, and in assisting him to visualize by rendering from one form of expression to another. It is, therefore, profitable to learn to sketch from drawings as well as from objects.

As a preparation for sketching, freehand object drawing

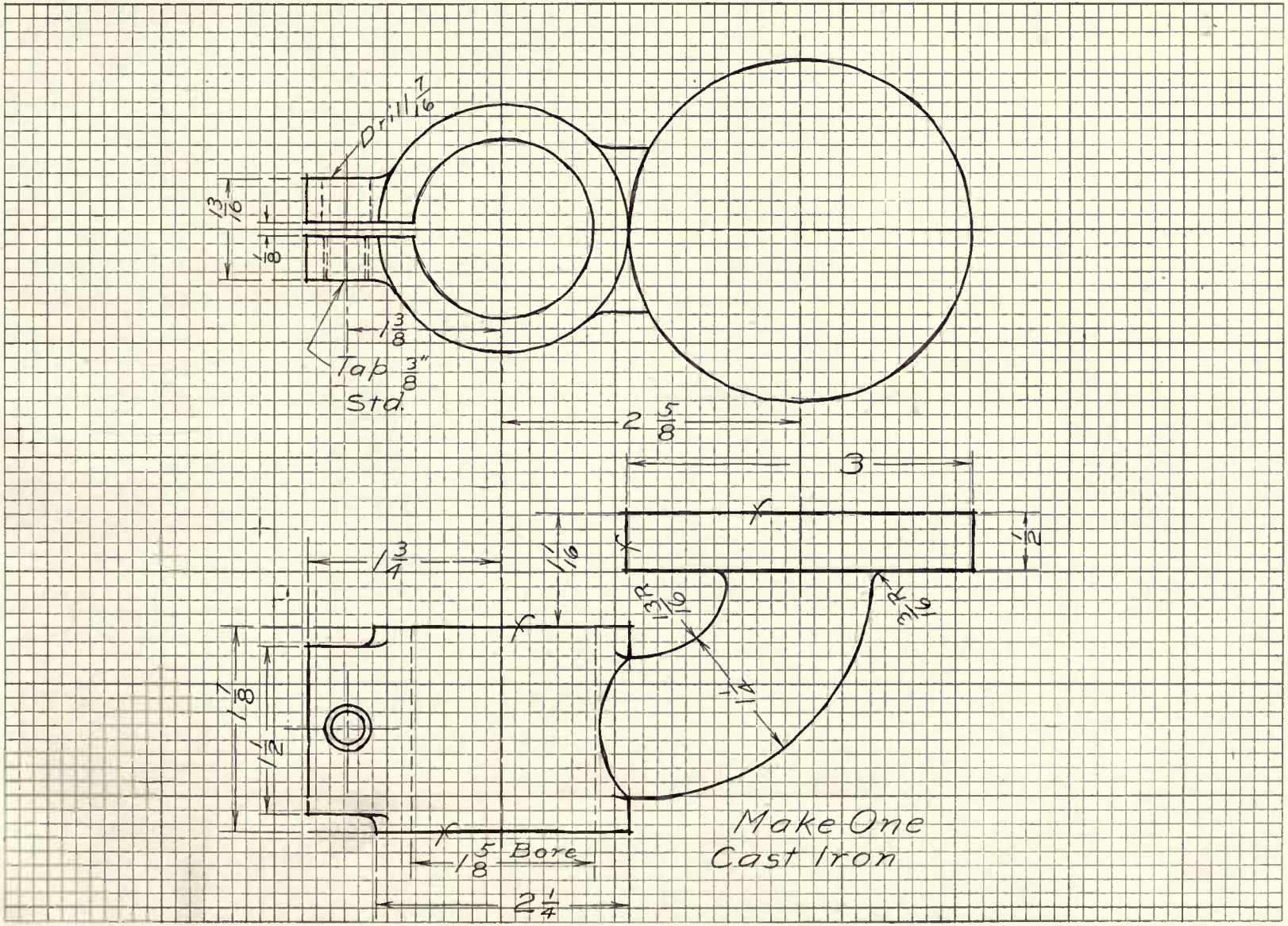


Fig. 159.—A Working Sketch.

is valuable, as the methods of the latter are employed in this work.

234. The method followed in making the "working sketch" is essentially that of the working drawing, therefore the principles of the latter should be understood and applied.

The object to be shown should be represented in its natural position and not drawn to scale. All distances should be estimated and no measurements taken until the drawing is finished.

The object should be drawn in good proportion, and if it is symmetrical, the sketch should show it.

The use of ruled, or cross-section, paper is advised for sketching. See Fig. 159.

235. The order of sketching may be stated as follows:

1. Study the object and decide which views are required. Block out the space for each view by points—views must be properly related.

2. Draw center lines.

3. Draw the outlines of the characteristic view, then of the others.

4. Draw the large details, then the smaller ones.

5. Draw the extension and dimension lines. Remember that the length, breadth, thickness, and location of each detail must be shown.

6. Take measurements and enter them.

7. Place on the notes, finish marks, date, name of part, and machine to which it belongs.

CHAPTER X

BLUE PRINTING

236. In the commercial drafting room the original drawings are usually made on buff detail paper in pencil. A tracing in ink is made on transparent paper or cloth and from the tracing any number of " prints " may be made. The method of making a tracing was explained in paragraph 42.

The original drawings and tracings are kept on file in the drafting room—the tracings in a fire-proof vault, the prints only being sent out on the " job."

The blue-print process is used most extensively to produce shop prints. It has the advantage of being simple and inexpensive.

A blue print is made by exposing a sensitized paper to the light in contact with the tracing or negative, and afterward washing or " fixing " it in a bath. It is a chemical process from start to finish.

237. Blue-print paper is prepared by coating or " sensitizing " the surface of a good white paper with a solution which is made and applied as follows:

A. Ammonia citrate of iron (red crystals), 1 oz., dissolved in water, 6 ozs.

B. Potassium ferricyanide, 1 oz., dissolved in water, 6 ozs.

These solutions are kept separate in a dark room until used.

Mix A and B in equal quantities and apply evenly to the surface of the paper with a camel's-hair brush. After the solution has set, hang the paper up to dry.

238. The commercial papers are designated as *slow*, *rapid*, and *extra rapid*, according to the time required for printing, which depends upon the formula used in preparing the solution. The formula given above is for the ordinary or slow-printing paper.

For a rapid-printing paper the following formula may be used:

A. Ammonia citrate of iron (green crystals), $1\frac{1}{3}$ ozs., dissolved in water, 6 ozs.

B. Potassium ferricyanide, $\frac{1}{2}$ oz., dissolved in water, 6 ozs.

Take equal volumes of A and B.

For an extra rapid or so-called " electric " solution the following is a formula:

A. Tartaric acid, $1\frac{1}{2}$ ozs. Water, $6\frac{1}{2}$ ozs. Ferric chloride solution (sp.gr. 1.45), 1 oz. Liq. ammonia (.880), 3 ozs., added slowly to neutralize.

B. Potassium ferricyanide, 1 oz. Water, $4\frac{1}{2}$ ozs.

Take equal volumes of A and B.

The extra rapid or electric solution deteriorates very quickly and is therefore not recommended for general use. A good quality of rapid paper will usually meet all the essential requirements as to speed in printing.

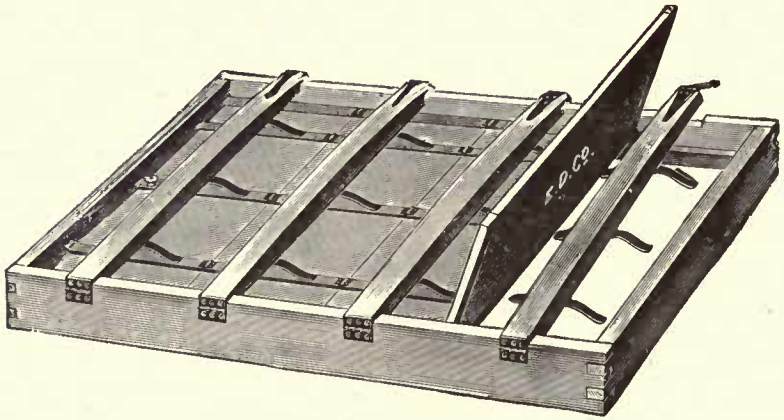


FIG. 160.—A Printing Frame.

239. In the preparation of commercial papers, the solution is applied to the surface of the paper by a machine. A continuous roll of paper is drawn through the machine, coated, dried, and re-rolled. It is then cut up and wrapped in 10- and 50-yard rolls, made in widths from 30″ to 54″. When blue-print paper is thus obtainable, it does not pay to make it.

Blue-print paper must be handled and stored in a dry place and exposed only to an orange or a ruby light. It will spoil in a white light and it deteriorates rapidly with moisture.

240. Blue prints are made, first, by exposing the tracing in a printing frame as shown in Fig. 160. The tracing is laid on the glass face, ink side down, and the paper is placed with its face (sensitive side) on the tracing. A pad of felt is laid on the paper to press it evenly against the tracing, and the frame is then closed.

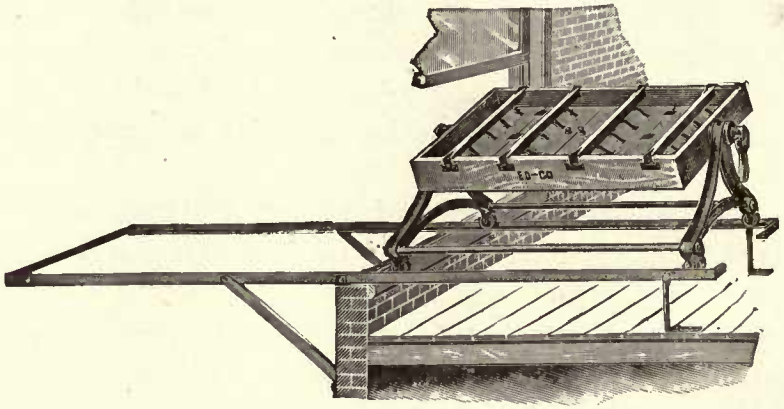


FIG. 161.—A Printing Frame on a Track.

The frame is next brought out of the darkened room into the sunlight and placed with the glass toward the light, selecting a spot that is free from shadows.

The length of exposure will depend upon the degree of sensitiveness of the paper, its freshness, and the strength of the light. A fresh rapid paper in the bright sunlight of summer mid-day will print in one minute from an ink tracing on cloth. A slow paper on a dull winter's day will require ten minutes or even longer. Tracings on cloth print faster than tracings on paper, and old prints faster than fresh blue-print paper. All the factors must be considered, then determine the time exactly by trial.

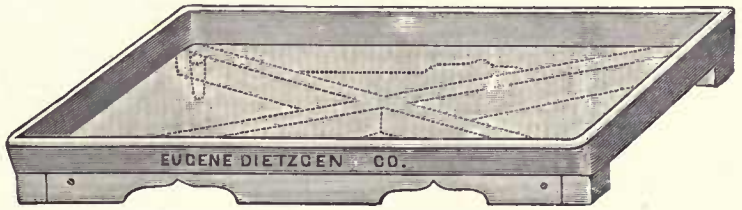


FIG. 162.—A Washing Tray.

For making large prints a heavy frame mounted on a track is often used. See Fig. 161.

241. The next step is to wash the exposed print in a tray of cold water for about ten to fifteen minutes; running water is preferable. It is then hung up to dry. See Fig. 162.

Caution: Do not handle the tracing or unexposed paper with moist hands. Water will ruin a tracing and finger marks will spot the paper.

After washing, the print should have a dark-blue color with clear white lines. The effect of the light is to reduce the ferric salt to ferrous salt, which combines with the ferricyanide and precipitates Turnbull's blue, thus forming a new compound which is permanent. The opaque lines of the drawing prevent the light from penetrating and, as no action takes place, the original chemicals are washed out, leaving the white lines on a blue ground.

A pale blue color indicates that the print did not have sufficient exposure. If the lines of the print are not clear and white, it was overexposed. If overexposed long enough the print will reverse, that is, the lines will be blue and the ground a light gray.

242. Poor prints may be intensified by immersing them in a bath made as follows:

Bichromate of potassium, $5\frac{1}{2}$ ozs. Common salt, 4 ozs. Water, 1 gal.

Add one cupful of the above

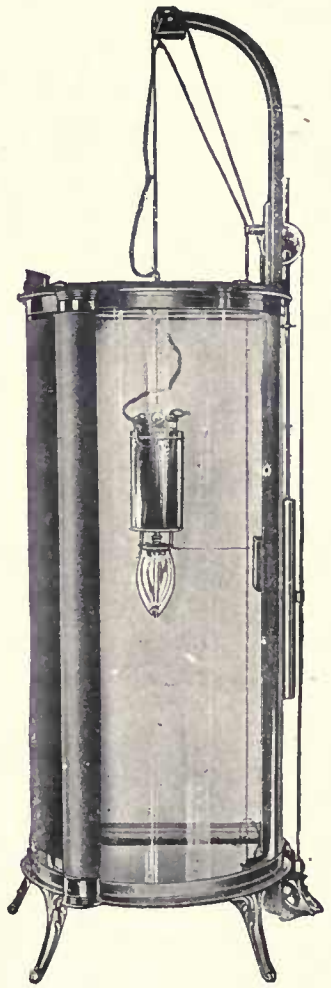


FIG. 163.—Electric Blue-Printing Machine—Vertical Type.

solution to a tray full of water, mix thoroughly, then immerse the prints. The prints must be thoroughly rinsed with clear water before hanging up to dry.

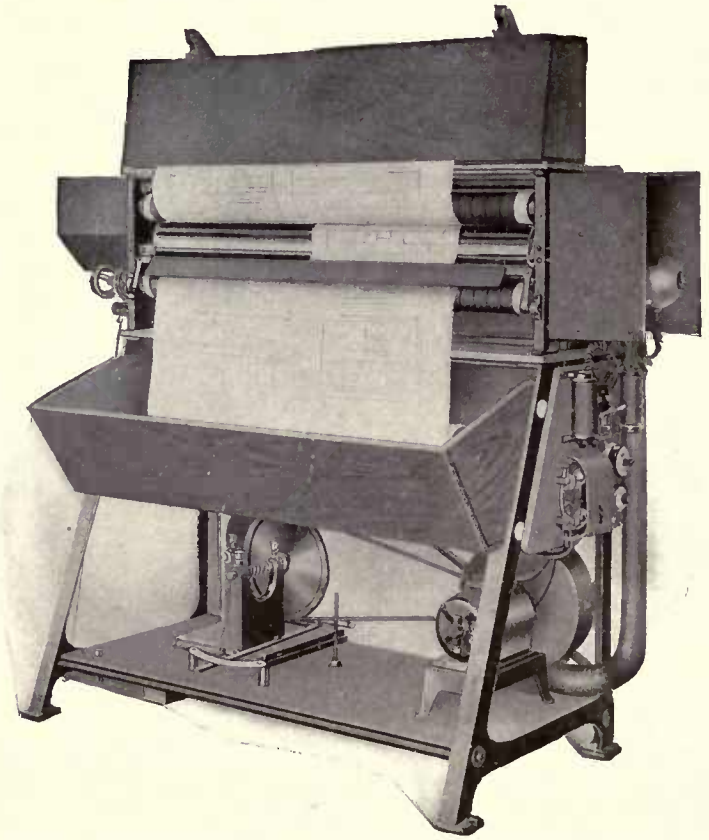


FIG. 164.—Electric Blue-Printing Machine—Horizontal Type.

Water that is alkaline will weaken the prints. Such water should be neutralized with a little citric acid.

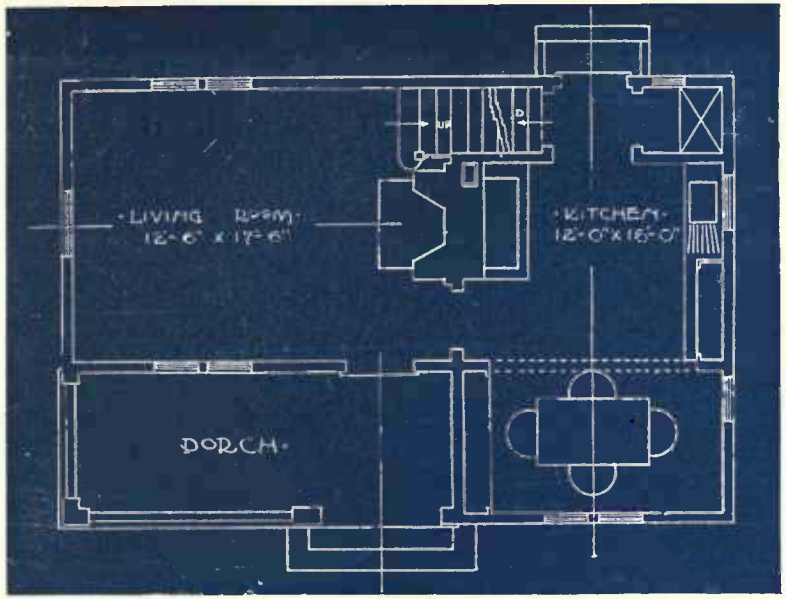
243. Electric printing machines are used extensively. The vertical type shown in Fig. 163 has an arc lamp with a vertical feed. The tracing and the paper are wrapped around the glass cylinder. The exposure is regulated by the time allowed for the lamp to travel the length of the cylinder.

A machine of the horizontal type is shown in Fig. 164. It has a mercury-vapor lamp which is placed inside a revolving glass cylinder; the lamp is stationary. Machines of this type are adapted to continuous printing, a roll of paper with the tracings being fed into it steadily.

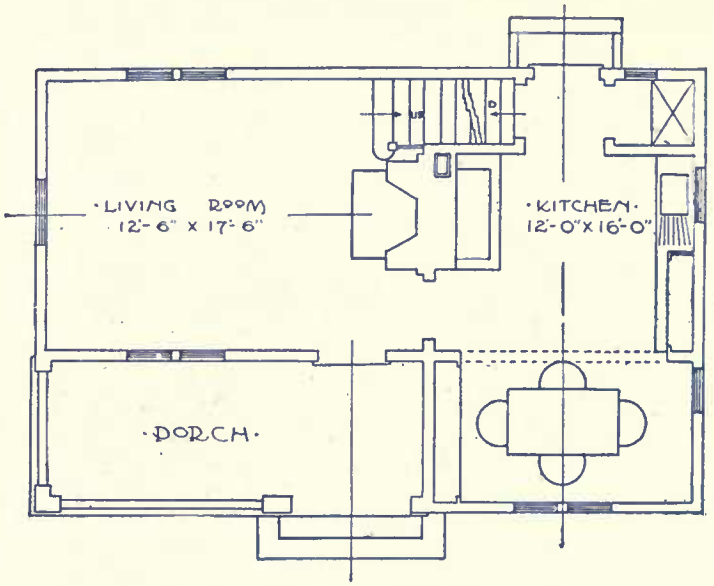
A continuous washing, drying, and ironing machine is shown in Fig. 165. The machine illustrated in Fig. 166 is an electric printing, washing, and drying machine. The tracings and a continuous roll of paper are fed into the machine; the prints are delivered at the end of the dryer automatically wound in a loose roll while the tracings are returned to the operator. This machine has a capacity of 100 lineal yards of blue prints per hour.

244. Alterations or corrections may be made on a blue print by using an alkaline solution, such as washing soda, caustic potash, or strong ammonia, which bleaches out the blue. After drying, the ink may be applied, or, if preferred, a few drops of carmine ink may be added to the solution and the changes made with a pen dipped into the tinted solution.

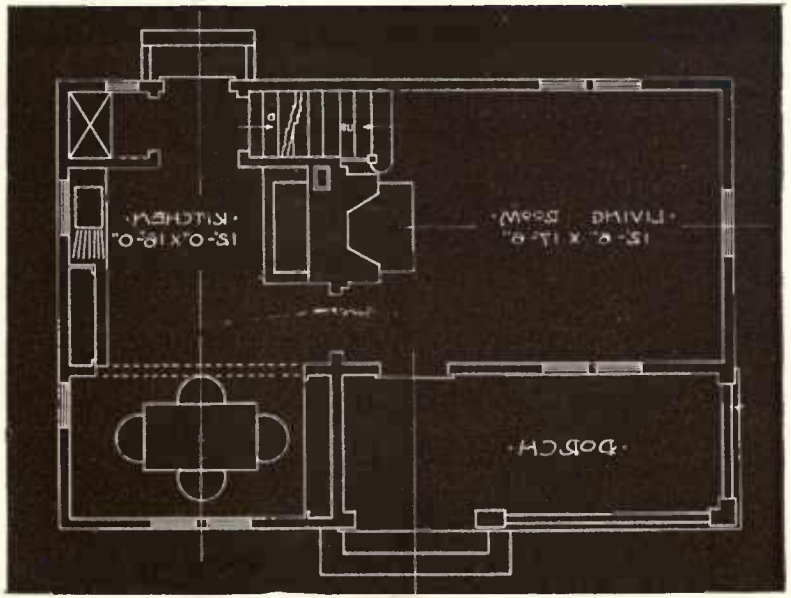
245. Prints are made also by other methods and are



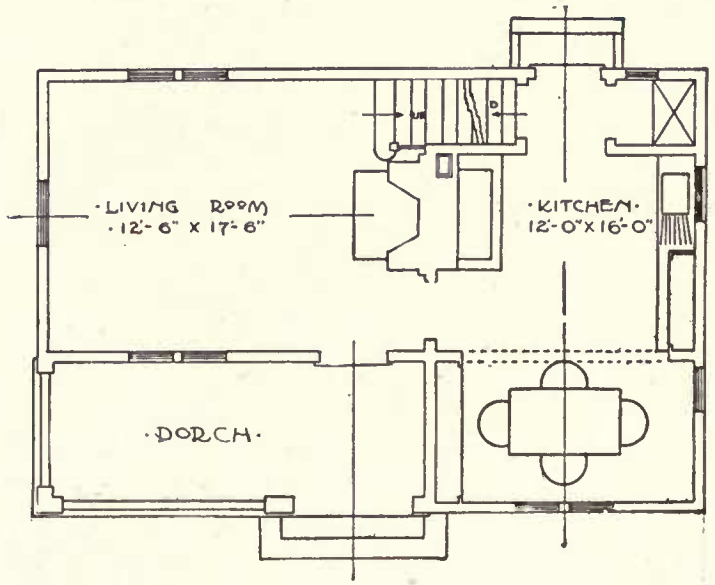
Regular Blue Print from Tracing of Original Shown in Fig. 113.



Blue Line Print from Van Dyke Negative.



Van Dyke Negative from Same Tracing as Above.



Brown Line Print from Van Dyke Negative.

known as "black" prints, "brown" prints, etc. **The Van Dyke print,** which is of dark-brown color, is used extensively. The process, however, involves an extra bath treatment, which is a disadvantage. Van Dyke paper is often used for making "negatives" from which prints having a blue line on a white background may be made from regular blue-print paper in the usual manner.

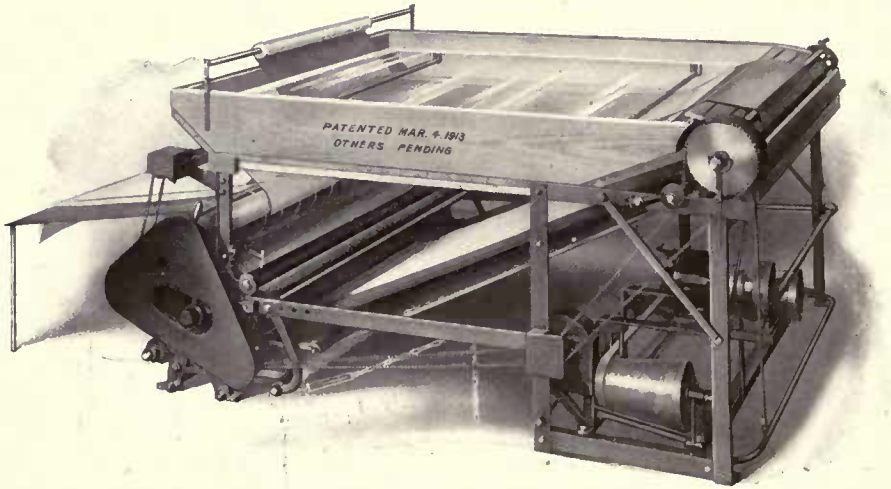


FIG. 165.—A Continuous Washing, Drying and Ironing Machine.

The negative is printed from a tracing which is placed "face up" in the frame instead of down. A positive print in blue or brown is made from the negative in the same way. See Plate XXXVIII.

246. Drawings made on bond paper or other papers not sufficiently transparent to print well may be treated by a preparation which will greatly facilitate printing, as follows:

White wax, 2 ozs. Alcohol (absolute), 15 ozs. Ether, 1 oz. Dissolve, and let stand in a closed jar until it settles,

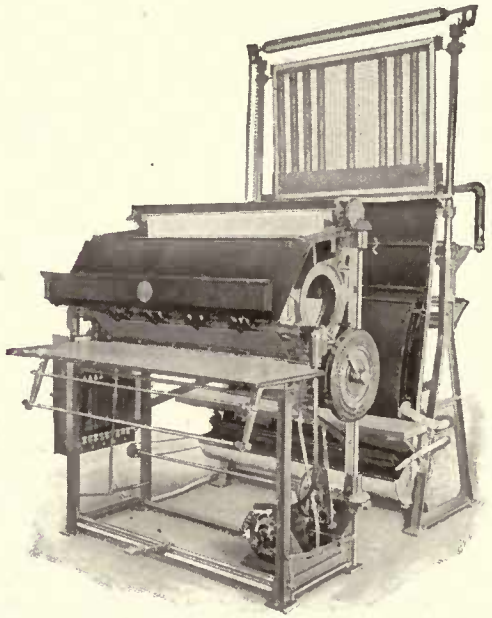


FIG. 166.—A Continuous Electric Printing, Washing and Drying Machine.

then pour off the clear solution into a tight bottle ready for use. Place the drawing to be transparentized upon a sheet of blotting paper or newspaper and apply the solution with a cloth or waste, wiping off the surplus.

Paraffin dissolved in benzine may also be used for this purpose.

247. A typewritten sheet may be blue printed by using a black ribbon on the typewriter and placing a sheet of carbon paper back of it, having the latter reversed from the usual manner, so that it will print on the back as well as on the front. A light bond or tracing paper should be used for this purpose.

Two or three good copies of small drawings may be made quickly by laying together alternate sheets of thin white paper and carbon paper, placing the original on top and tracing the lines with a 6H pencil.

248. The hektograph process for reproducing drawings has advantages where not more than 20 or 25 copies are desired. The original is prepared with colored ink on white paper. A special ink is required, but it may be had in various colors, any or all of which may be used on the original at the same time. This is a great advantage, as it is often desirable to differentiate lines by colors.

The original is then placed on a gelatine pad which absorbs the ink and transfers it to the paper to be printed. The directions supplied with the various types of hektographs on the market furnish the details necessary for their successful operation.

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